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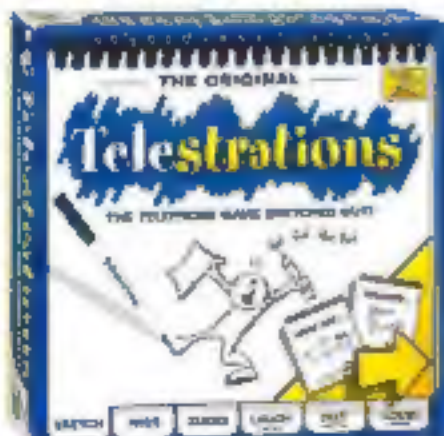
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WELCOME

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"Planes before this felt like an old movie. Now, it is like living in a Star Wars reality"

How to build a fighter jet, page 22

Meet the team...



James

Production Editor
Is it really possible to build a colossal lift that will take us from the Earth's surface into geostationary orbit in space? Find out on page 60.



Scott

Staff Writer
Discover how some symbiotic relationships in the animal kingdom aren't as mutually beneficial as they seem on page 64.



Rajeev

Research Editor
Discover how incredibly versatile the element carbon is and how it holds the key to almost all life on Earth on page 34.



Jon

Art Editor
As one of the most tragic maritime disasters, find out how the 'unsinkable' Titanic ended up at the bottom of the ocean on page 42.



Ailsa

Staff Writer
Today, photography provides us with instant images, but this wasn't always the case. Check out the first instant camera on page 54.



This issue we've been lucky enough to have been taken around a huge factory in Texas, one that builds F-35 fighter jets. These advanced air-combat vehicles are popped out by the

dozen in Lockheed Martin's impressive, hi-tech, and high-security Fort Worth facility. But you can find out exactly how they're made, step by step, on page 22.

Also, some of our pages in this 10th anniversary issue of **How It Works** are augmented reality-enabled. Just download the app from page 4, follow the instructions and keep an eye out for the AR logo in each feature. Enjoy!

Ben Biggs Editor



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MEET THIS ISSUE'S EXPERTS...



James Hartman
Former *HiW* member James is a technologist and future strategist. He is currently doing a PhD in machine learning and evolutionary theory.



Jo Stass
Editor and editor Jo is particularly interested in the natural world and learning about the latest in technology innovations.



Jodie Tyley
The former editor of *HiW* and *All About History* has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.



Laura Mears
Ran a medical equipment business and his job to write about science and is now looking towards her PhD in natural and artificial.

AR ZONE!

NEW

Download the Zappar augmented reality app on your mobile. Search for 'Zappar' from <https://www.zappar.com/bestdevices/>

When you see the **AR ZONE!** logo at the top of a page, use your Zappar app to scan the Zaprocode

Hold your mobile device over the pages and watch them come to life! Your device needs to be connected to the Internet for this to work.

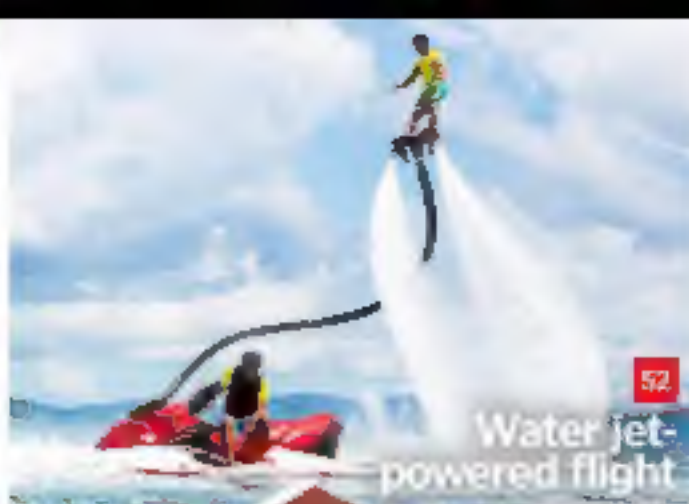
HOW THE ZAPPAR APP WORKS

When being activated by the Zaprocode, the app tracks anything you point your device's camera at 2D from a second, searching for distinctive shapes we've learned it to recognise. When it sees something familiar, it places the augmented reality 2D image on your screen. It's the magic, but actually just really clever technology.

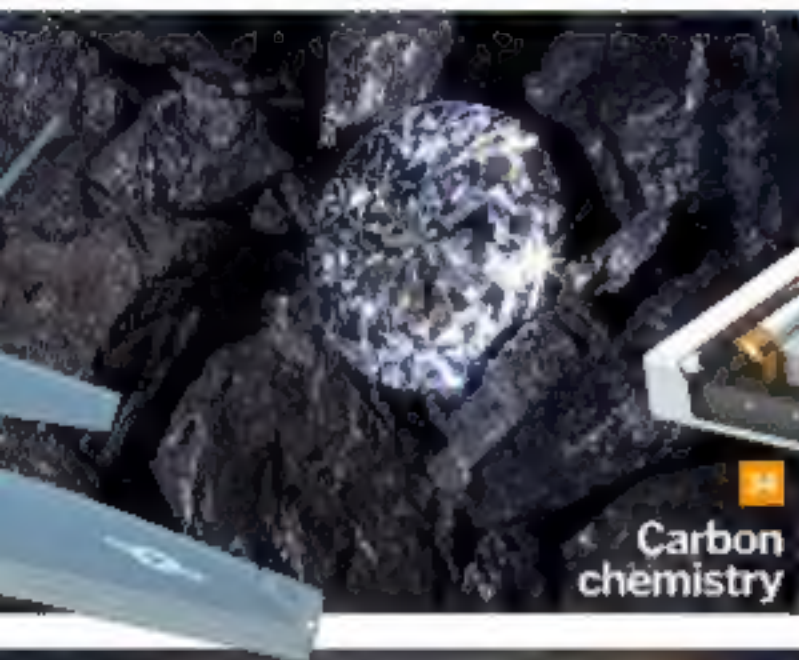
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WIN
TOYS AND GADGETS
WORTH OVER
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Stephen Ashby

Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.



Steve Wright

Steve has worked as an editor for many publications. He particularly enjoys history, horror, writing and regularly writes literature and film reviews.



Elizabeth Howell

Science and space journalist Elizabeth is based in Ottawa, Canada, where she teaches technical writing and is president of a science writing and communication society.



Tom Lean

Tom is a freelance science writer at the British Library, working on our history projects. His first book, *Blackout Britain*, was published in 2011.



Dr Andrew May

Andrew has a PhD in ecology and 30 years in public and private industry. He enjoys social writing and has written several books.




Soap bubbles splitting light

These are soap bubbles, clinging together to form an irregular cellular structure. Bubbles normally minimise their surface area for the volume of air they contain, creating a spherical shape. The iridescent surface sheen is where white light is refracted and split into bands of colour. The clear spots are too thin to refract, indicating the bubble is about to burst. This image was taken by Kym Cox for The Royal Photographic Society's Science Photographer of the Year competition. Find out about the competition at rps.org/spotv.







Seeing into the galactic centre

.....

This galaxy, designated NGC 3169 and photographed by the Hubble Space Telescope in July 2019, is around 70 million light years from us, and is a spiral galaxy. The galactic nucleus is mostly obscured by cosmic dust, but Hubble has managed to take a shot that allows us to see the centre, which is a source of 'hard' x-rays. Cosmic dust is made of ice, hydrocarbons and other materials. It is left over from the enormous amount of star and planet formation that has happened in this galaxy in the last billion years.



Tragic end for the beached whale pod

.....
This is one of five sperm whales stranded on the beach of Texel, a Dutch island, in 2016. Locals were unable to return them to the water and they died.

But why did this pod end up here in the first place? Scientists still don't know exactly, but they've been doing it in greater numbers. Sea pollution could affect mental development, while ship and submarine sonar could interfere with the whales' echolocation.



Every day, our global network of Live Science reporters, bloggers and photographers bring you the latest news and photos from the world of science. Follow us on Facebook, Twitter and YouTube for more.

The Fireworks Galaxy is famous for its supernovas (seen in infrared, but a supernova is a explosion (argued) two scientists scratching their heads.

Fireworks Galaxy flare-up baffles scientists

Words by Brandon Speckter

Don't be alarmed, but the Fireworks Galaxy is exploding. Admittedly, it's been exploding for a while—at least since 1977 (give or take the 25 million years that light takes to travel from that galaxy on Earth), when astronomers first glimpsed a large star erupting into a supernova there. Since then, scientists have detected nearly a dozen stellar explosions in the galaxy, but none quite like a mysterious green blotch of x-ray light recently observed.

What makes that blotch special? For starters, it's not a supernova. The x-ray signature detected by NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) is far more energetic than a typical supernova. But more importantly, the energetic x-ray blast also appeared and disappeared from the galaxy in about ten days—a briefer appearance than a supernova, which can brighten and fade over hundreds of days.

So, the greenish blast of invisible energy is probably not a supernova. What is it, then? A

recent study published in *The Astrophysical Journal* provides a few guesses. The authors of the study, who glimpsed the mysterious blast of energy by chance while studying supernovas in the Fireworks Galaxy, said the mystery explosion likely involves one of the most powerful objects in the universe—possibly a black hole or neutron star—tearing apart one of its stellar neighbors. While black holes are black, their outer edges glow with intense radiation when nearby objects get pulled into the black hole's orbit.

It's possible, according to a statement accompanying the study, that the source of the green blast is a black hole that devoured a nearby star. As the black hole's overwhelming gravity rips that star to shreds, stellar debris could start spinning around the hole. The debris closest to the hole's event horizon could orbit so quickly that it gets hundreds of times hotter than the Sun in our Solar System. The debris could then radiate x-rays as it gets sucked into oblivion.

A neutron star, the ultra-dense corpse of a once-mighty star, could also be the culprit here. Neutron stars exert a gravitational pull billions of times stronger than Earth's.

However, these stellar corpses spin so blazingly fast that it can be impossible for nearby debris to reach the object's surface.

Sometimes, however, a wobble in a neutron star's magnetic field can slow the object's rotation enough for debris to get pulled into the star's glowing hole of destruction, a

black hole. The pulling in of debris could result in the sudden appearance and disappearance of an x-ray blast, like the one seen here. If that's the case, another flash of radiation is likely to appear in the same spot, following a future magnetic field wobble.

Scientists will continue monitoring the Fireworks Galaxy for possible repeat performances of this unusual x-ray event, waiting for another unlucky star to go out with a bang.

HEALTH

'Chemical exposure' linked to mysterious vaping disease

Words by Rachael Retimer

The number of Americans struck with mysterious, vaping-related lung diseases is rising. The Centers for Disease Control and Prevention (CDC) has announced that it is aware of 400 possible cases of severe lung illnesses linked to vaping that are under investigation in 11 US states. Three deaths have been confirmed in connection with these illnesses. Many of the patients are teens or young adults. All patients reported using e-cigarettes, and many used the devices to vape marijuana.

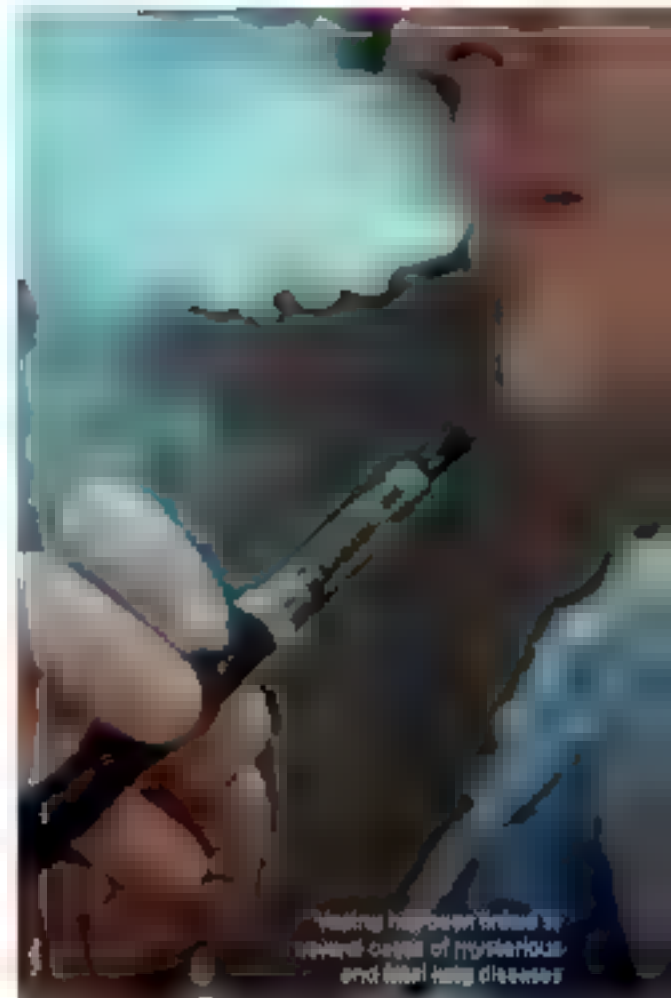
So far, the cause of the illnesses is unknown, but a single vaping device, produced in the Netherlands, often found in the cases, said Dr David Mennery-Delmon, the manager of the CDC's investigation. Officials believe chemical exposure is likely to be behind these illnesses, but much more information is needed, Mennery-Delmon says.

The CDC announcement coincided with the release of several new reports on vaping-related illnesses. One, published in *The New England*

Journal of Medicine, describes 33 patients from Wisconsin and Illinois who developed respiratory symptoms after vaping. Most of these patients were young, male and healthy prior to their illness. Patients had symptoms such as shortness of breath, coughing and chest pain, nausea, vomiting, fever and weight loss. All of the patients had vaped within the prior three months, and 84 per cent reported vaping marijuana products.

The report seems to suggest that vaping-related lung illnesses are a new phenomenon, and not something that simply went undetected in the past. The rate of monthly emergency room visits for severe lung illness in young adults was twice as high in June to August 2019 as the same months in 2018, the study found.

The CDC recommends that people consider not using e-cigarettes while the investigation is ongoing, and should not be used by children or adolescents, young adults, pregnant women or adults who currently don't use tobacco products.



Vaping has been linked to several cases of mysterious and fatal lung diseases

ANIMALS

T



"An autopsy revealed two small lacerations on her leg, one of which was over a large varicose vein"



Attacks by roosters are rare, but they can be deadly and a heavy injury

STRANGE NEWS

Woman pecked to death by rooster

Words by Rachael Rettner

A woman in Australia who was attacked by a rooster died after the bird's pecking caused her leg to bleed profusely, according to a new report of the case.

The 76-year-old woman was collecting chicken eggs in her rural property when an aggressive rooster began pecking at her lower-left leg, according to the report, published in the journal *Forensic Science, Medicine and Pathology*. The pecking resulted in significant hemorrhage, which caused the woman to collapse, the report said. An autopsy revealed two small lacerations on her leg, one of which was over a large varicose vein. Doctors concluded that the woman died from "exsanguination" due to bleeding from a varicose vein following the rooster attack, the report said.

Varicose veins are usually not harmful. But in rare cases, they can cause complications, including bleeding that is difficult to stop, according to the NHS. In a 2012 report published in the journal *BMC Research Notes*, researchers from Greece described the case of a 66-year-old woman who died from bleeding due to a ruptured varicose vein. Underlying conditions, such as heart disease, may increase the risk of death from varicose vein bleeding.

Attacks by roosters are "very rare," Dr. Roger Byard, a professor of pathology at the University of Adelaide and co-author of the new report, told the Australian Broadcasting Corporation (ABC). "This case demonstrates that even small domestic animals may be able to inflict lethal injuries on individuals if there are specific vascular vulnerabilities present," the report said.

STRANGE NEWS

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HEALTH

First left-handed genetic markers found

Words by Rachael Rettner

Scientists have discovered the first genetic markers tied to being left-handed, according to a new study. In addition, these genetic markers may play roles in brain development and communication between different brain areas, the authors said. The findings, published in the journal *Brain*, shed considerably more light on the biological processes justifying left-handedness, study lead author Dr Akira Wiberg, a research fellow at the University of Oxford, said in a statement.

About one in 10 people worldwide are left-handed. Scientists have known that genes contribute to being left-handed, but they didn't know which genes are involved. In the new study, the researchers analyzed the genomes of about 400,000 people in the UK whose health records and genetic data are part of a database known as the UK Biobank. Of these, about 38,000 were left-handed.

The researchers looked for differences in the DNA of left versus right-handers, and they identified four genetic markers tied to being

left-handed. Three of these markers were located in genes that provide instructions for making proteins involved in brain development and structure. For example, some of these genes were involved in the set up of microtubules, which make up the scaffolding inside cells, known as the cytoskeleton.

The researchers also analyzed brain scans of about 10,000 participants and found that these genetic markers are linked with differences in the brain's white matter — long nerve fibres that allow areas of the brain to communicate. In particular, three of the markers were most pronounced in tracts connecting language-related regions in the brain. "We discovered that, in left-handed participants, the language areas of the left and right sides of the brain communicate with each other in a more coordinated way," Dr Wiberg said.

This finding suggests that left-handers might have an advantage when it comes to performing verbal tasks, but much more research would be needed to show this, he said.

Left-handed genetic markers may play a role in brain development



This photo of Nessie from 1934 turned out to be a hoax created with a toy submarine and a fake bee monster. Study

SCIENCE NEWS

Loch Ness contains no 'monster' DNA

Words by Tom Ichniowski

The Loch Ness monster has haunted a deep Scottish lake for more than 1,500 years — in imagination, at least. But a scientific survey of the waters of Loch Ness found it contains no traces of "monster" DNA, at all, adding weight to the already likely prospect that 'Nessie' doesn't really exist.

Geneticist Neil Gemmell of Otago University in New Zealand said an environmental DNA survey of Loch Ness saw no signs it was home to any giant reptiles or

aquatic dinosaurs — a theory sometimes used to explain the mysterious monster, which has reportedly been seen several times since the 1930s. Gemmell said the survey revealed DNA traces of more than 2,000 species living beside or in Loch Ness — including fish, deer, pigs, birds, humans and bacteria. But "we did not find any giant reptiles; we didn't find any reptiles at all," Gemmell told *Live Science*. "We tested a variety of ideas about giant sturgeons or catfish that might be here

from time to time, but we did not find those either," he explained.

One thing the researchers did find is that Loch Ness contains a lot of eels. And the researchers say it is possible, although a tad likely, that sightings of Nessie may actually be sightings of overgrown eels. "Out of the 100-year-old water samples that we took, pretty much every single sample has got eels in it," he said. "But are they giant eels? I don't know," he said.

HISTORY

Salt saved ancient scrolls from destruction

Words by **BRADY HENNING**

The Dead Sea Scrolls are a marvel. Buried for roughly 2,000 years under piles of debris and bat guano in a chain of caves in the Judean desert, the collection of nearly 1,000 fragments of manuscripts includes biblical texts, a calendar, legends and early astronomical observations. Among these mysterious artifacts—many of which have only just topped scraps of parchment—are impeccably preserved documents that date out.

The Temple Scroll, named for its description of a Jewish temple that was never built, is one of the longest, richest, best-preserved and easiest scrolls to read. Why, out of thousands of faded fragments found in the Judean caves, has the Temple Scroll lasted so well after two millennia?

A new study published in the journal *Science Advances* researchers attempted to find out by scrutinizing a piece of parchment using every x-ray and spectroscopic tool at their disposal. They found that the scroll—admittedly, a fragment—had something that other writings did not: traces of a salty mineral solution not present in

The Temple Scroll, one of the longest and best-preserved of the Dead Sea Scrolls.

any other previously studied scroll, nor in any of the caves or in the Dead Sea itself. Understanding the properties of these minerals is particularly critical for the development of suitable conservation methods for the preservation of these invaluable historical documents, the researchers wrote in the study.

Prior studies revealed that the Temple Scroll was unlike most other Dead Sea fragments in that it was composed of several distinct layers: an organic layer made of the animal skin that served as the parchment's base, and an inorganic layer of minerals that may have been rubbed on during a parchment finishing process.

To figure out what this inorganic layer was made of, and whether it was rubbed there intentionally, the team studied a segment of the Temple Scroll using x-ray scans and Raman

spectroscopy, a technique that reveals the chemical composition of a substance by watching how it absorbs light, scatters it and vibrates thermal elements. The researchers found that the scroll was coated in a mixture of salts made from sulphur, sodium, calcium and other elements, however, these salts did not match elements found naturally in the cave, dug out in the Dead Sea, ruling out a natural origin.

It is possible that this salt coating has contributed to the Temple Scroll's uniquely well-preserved appearance, the researchers said—but it could also be an indication of the scroll's eventual destruction. As the salts detected on the scroll are known to break down, one of the alternative theories could be that the scroll's degradation "if not stored properly," he said.

SPACE

Soyuz MS-14 landed 140 kilometres south-east of the town of Zhezkazgan in Kazakhstan.

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Soyuz MS-14 landed 140 kilometres south-east of the town of Zhezkazgan in Kazakhstan.

A solar visitor is seen in the aurora

Words by Stephanie Pappe

A strong solar storm has brought the northern lights further south than usual, and it may have included something different than the aurora: a solar visitor dubbed STEVE. Researchers discovered STEVE, short for the strong thermal emission velocity enhancement, in 2018.

What makes it strange is that its light comes from across the spectrum, without the peaks in particular wavelengths that characterize regular auroras. "The big thing is we can clearly say now, it's not regular aurora," University of Alaska Fairbanks researcher Don Hampton, who recently analysed a STEVE event from 2018, said in a statement. "It's a new phenomenon - that's pretty exciting."

The northern lights occur when charged particles from the sun excite electrons in Earth's atmosphere. As a result, these electrons first move to a higher energy state,

then settle down to their original, lower energy state. As they do so, each one releases a photon, a particle of light. The colour of the auroral light depends on the molecules the charged solar particles hit. If they hit oxygen, green and yellow result, for example, while nitrogen tends to make red and violet. STEVE, though, consists of light from across the electromagnetic spectrum, with a slight boost in the red range, explaining the phenomenon's mauve colour.

The new findings confirm that the particles that produce STEVE are quite fast. "When you turn your electric stove on, those coils get red hot, right? If you look at it with a spectrograph, you would see broad band emission," Hampton said in the statement. Similarly, STEVE's broad range of wavelengths indicate heat. "So, this is like very, very warm atmosphere emissions of some sort."

The researchers made their measurements using a new piece of Earth-based equipment called the Transition Region Explorer (TNE) spectrograph, which measures light wavelengths. Using this instrument, investigators captured a view of STEVE on 10 April 2018, near Lucky Lake, Saskatchewan.

As has often happened, STEVE was accompanied by a green 'picket fence' phenomenon, which consists of vertical, green bands of light that cross STEVE's usual pink bands. By looking at the wavelengths, the researchers confirmed that the picket fence is a variation on the usual aurora.

The next step, Hampton said, is to figure out how or if STEVE affects humanity. Solar storms that cause the aurora can also disrupt satellite communications, and it's not yet clear whether STEVE does the same thing or if its impact differs.

By
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Australian students in birds save finches

By Yasemin Sahinoglu

A primary school in Australia is breeding

finches

save them, according to the Australian Broadcasting Corporation (ABC).

The southern subspecies of the black-throated finch, called *Hoopoe cincta cincta*, is native to northeastern Australia. It is thought to be extinct in New South Wales, and only an estimated 2,000 are left in the wild in Queensland, according to the ABC.

In the classroom, they're thriving. Brett Murphy, a science, technology, education and media (STEM) teacher at the Bulga Gardens State School in Australia, started the breeding program seven years ago, and with the help of his students has been successfully breeding the finches for the past six years. In the breeding program, the team now cares for 120 finches, which includes the black-throated finch (*Hoopoe cincta*) and other species, such as the Gouldian finch (*Erythrura gouldiae*). Students take care of these birds every week, feeding them and making observations of their health.

But while the breeding program is useful for raising awareness and appreciation, it will not save the finches lost in the wild. Tony Orice, a member of the Federal Black-Throated Finch Recovery Team, told the ABC. The main threat to the species is habitat loss, he said. These finches thrive in open, grassy woodlands with water nearby. "Some of that loss is historical, and some, more recently, is loss of the woodlands it prefers to live in and degradation of those woodlands to waterways," Orice said. Breeding birds in captivity won't provide that habitat.

"In the breeding program, the team now cares for 120 finches"

Parents panicked when their babies grew a thick layer of hair



Spanish babies develop 'werewolf syndrome'

Words by Isabel Whitcomb

Parents in Spain started panicking this summer when 17 children and babies mysteriously came down with hypertrichosis, or 'werewolf syndrome', a condition where their bodies and faces became covered in a dense layer of hair, according to news reports.

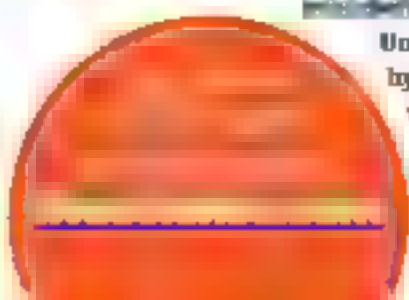
At first, doctors couldn't figure out what was wrong. Was it genetic? A metabolic disorder? At the end of August the Spanish Health Ministry finally announced that it had discovered the root of the problem. In a pharmaceutical mix-up, babies across Spain had been inadvertently dosed with a medication for alopecia, or hair loss. All the affected children had one thing in common: they

were all taking the same medicated formula that supposedly contained omeprazole, a drug used to

Early in July, the drug was identified as a suspected culprit for the condition and pulled from the shelves. A later investigation by Spain's Agency for Medicines and Health Products (AEMPS) revealed that instead of omeprazole, the formula the babies were drinking contained minoxidil, a drug used to stimulate hair growth. The mix-up happened when, at some point in the packaging process, the medication was

Unlike people with genetic hypertrichosis, the babies affected won't stay hairy: the excess hair should fall out after a few months.

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So far 2019 has seen an increasing number of launches for smart glasses, each with their own approach to streamlining the way we receive information from our phones. Vue is no exception. Designed with style in mind, these sleek glasses use bone-conduction technology to play music and phone calls in your ear. Once Bluetooth-paired with a smartphone, the wearer can change songs, answer calls or request the time with just a swipe or tap of the frame.



Leaf Chakra

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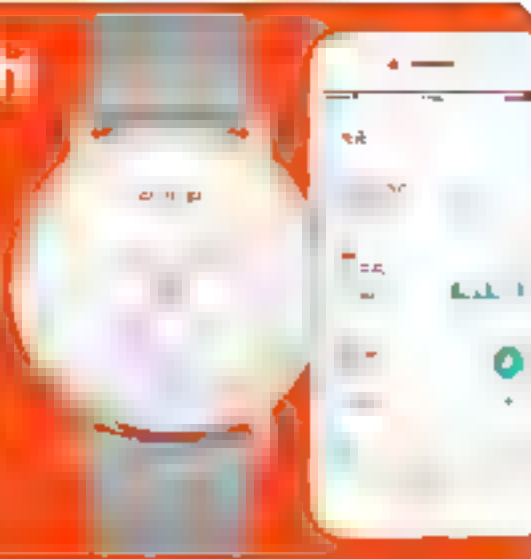
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Bellabeat has become one of the leading companies for combining women's fashion and technology. With an entire range of wellness trackers, the Leaf Chakra is a great addition to your arsenal of wearable technology. Worn as either a pendant or clip, this piece of high-tech jewellery can keep track of your sleep, meditation, fitness and reproductive health. Set reminders, alarms and follow in real time how your body is performing throughout the day with the accompanying app, jam-packed with your daily stats.



Move ECG watch

Move ECG watch is a smartwatch that can monitor your heart rate and ECG. It's a great way to keep track of your health and fitness. The watch is available in black, silver, and gold. It has a 1.4-inch display and a 1.2-inch ECG sensor. The watch is water-resistant and has a battery life of up to 7 days. It's a great gift for anyone who is health-conscious.



Matte Parliament

Price: \$89 (approx £75)

[Check it out!](#)

If you often find yourself stumbling through your wallet for the right credit card, ID or gym membership, then Ekster's smart wallet is for you. Coming in a range of styles and colours, this trigger-controlled wallet reveals your cards at the touch of a button. Making sure you're never without a way to pay, Ekster's range of wallets come with a pouch to house Ekster's tracker card. It can track your wallet around the world: by using the accompanying app these Bluetooth-paired wallets can be easily located when lost.



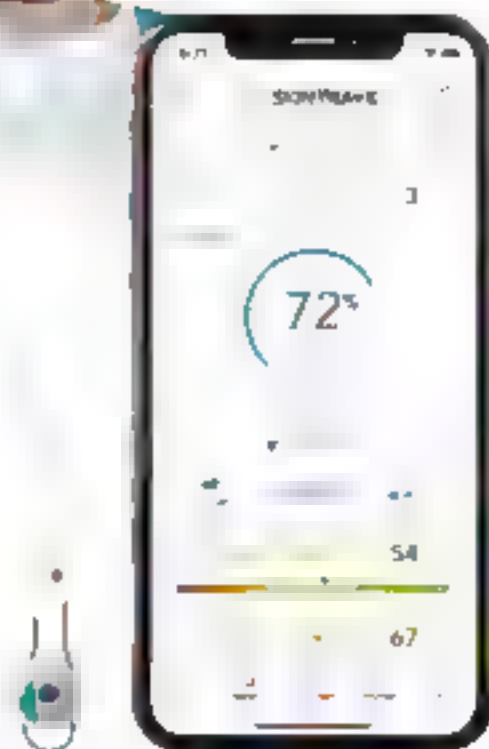
My Skin Track UV

Price: £54.95 / \$59.95

[Check it out!](#)

Basking in sunlight on a tropical beach can be great for the mind, but terrible for the body if you don't protect yourself from harmful UV radiation. My Skin Track UV wearable sensor works to keep you protected in real time.

Personalised to your skin type, tone and concerns, this compact sensor can alert you when you've spent too long in the sun and when it's time to top up your protection. Using the app you can monitor your daily progress and also receive in real time humidity, pollution and pollen updates.



APPS & GAMES



Wanna Kicks

Developer: LLC WANNABY

Price: Free / Google Play / App Store

Try before you buy has gone virtual with this augmented reality app. Simply select the shoes you want to try and see their appeal on your feet through the phone's camera.



Smart Closet - Fashion Style

Developer: Rabbit Tech Inc.

Price: Free / Google Play / App Store

Search through clothes from thousands of brands and upload pictures of your wardrobe to this smart style app, which will offer outfit suggestions based on your style.



Inkhunter

Developer: INKHUNTER, Inc. / Kateryna Rhotkevych

Price: Free / Google Play / App Store

Getting a tattoo is a lifelong commitment, but with this digitised tattoo app you can search through different designs or upload your own and virtually try them out on your skin.



Body-Scan

Developer: Sizee Technologies / Body-Scan Inc.

Price: Free / Google Play / App Store

Shopping for the right size online can be rather challenging, but this body-scan app can record your body measurements, enabling you to buy the clothes that fit you best.





IT WORKS VISITS THE
FACTORY THAT
STEALTH FIGHTERS FOR
AND THE WORLD

HOW TO

BUILD A FIGHTER

The fully integrated headset for the F-35 allows the pilot a 360-degree view while in the cockpit

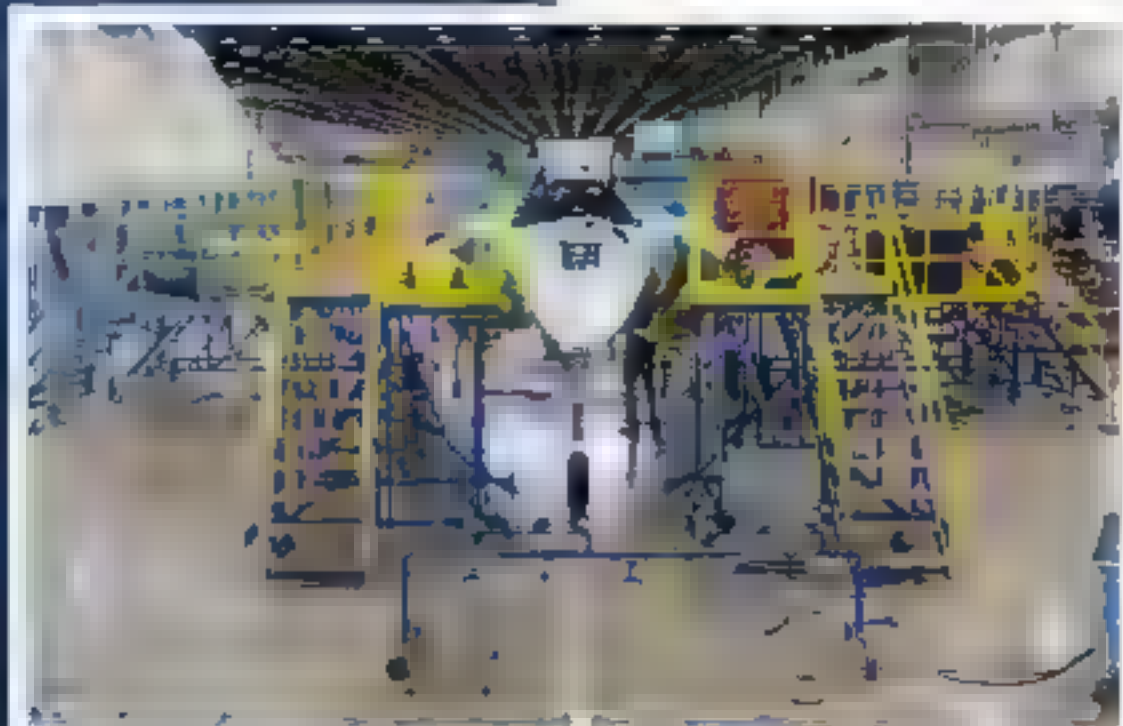
Just a short drive away from Dallas, Texas is the town of Fort Worth—home to the massive and super-secure facility where one of the world's most advanced fighter jets is built.

Lockheed Martin has thousands of people working here around the clock on the F-35. In fact, about 28,000 employees work in the aerospace business in Fort Worth—too many to list on the door at one time, so people work in shifts. There are engineers, technicians and machinists. Then there are the many people that support them as they build the plane—the cleaners, the cafeteria workers, the security personnel and so many more.

Visitors zip down the pipeline carts, carefully stopping at pedestrian crossings on the way. On either side of each aisle is a marvel of engineering—the F-35 coming together, piece by piece: wings, cockpit, tail fin, fuselage. Electronic screens mounted above each F-35 show what country it's destined for, and how well the workers are meeting their deadlines.

It's an awe-inspiring sight to see something so technologically advanced being assembled before your eyes. Towards the end, the green-painted body transforms into grey sophistication in the painting room, where two car-sized machines called T-hut and Zerk finish workers with its details work. The fighters emerge cloaked in low-visibility gray, and after a few more checks go to a flight line, where they are

"Lockheed Martin has thousands of people working around the clock on the F-35"





tested in flight. Each F-16 must pass a series of flight tests before being shipped to their customers, which include the UK, Turkey, Belgium, Denmark, Australia, Israel and others. So in a sense, this town-sized facility is a gateway to the entire world.

The largest building in the factory was once the biggest air-conditioned room in the world. Air conditioning was rare during the years of World War II, when President Franklin D. Roosevelt chose Ford's Ford as a way to build US bomber planes. But it's a necessary thing. It stops plane parts from warping, which would make construction difficult, and of course it's a lot more comfortable environment for workers.

Many aircraft companies worked here over the decades, finally ending up with Lockheed

"Lockheed Martin was producing the popular F-16 and later the F-22 fighters"

Martin in the 1990s. Lockheed Martin was producing the popular F-16 and later the F-22 fighters at the time. But while the company had a reputation for reliable fighters, military leaders worldwide were itching for something new.

What they needed was a 'fourth-generation fighter' – a plane that only had a small signature in radar, meaning that it would be difficult to detect. They wanted an electronic cockpit that the pilot could change, so that they would have the information needed for any mission. And they wanted a fighter that was a good bet for the future, something that could interface with drones and could carry at least weaponry.

Lockheed Martin's proposal to build the F-35 won the military, and in October 2001



Rise of the modern fighter jets

McDonnell Douglas F-15 Eagle

The McDonnell Douglas F-15 Eagle is a highly maneuverable fighter jet that has been one of the most successful fighters in the world.

General Dynamics F-16 Fighting Falcon

The General Dynamics F-16 Fighting Falcon is a multirole fighter jet that has been one of the most successful fighters in the world.

Boeing F/A-18E/F Super Hornet

The Boeing F/A-18E/F Super Hornet is a multirole fighter jet that has been one of the most successful fighters in the world.

Boeing F/A-18E/F Super Hornet

The Boeing F/A-18E/F Super Hornet is a multirole fighter jet that has been one of the most successful fighters in the world.

Dassault Rafale

The Dassault Rafale is a multirole fighter jet that has been one of the most successful fighters in the world.

Lockheed Martin F-35 Lightning II

The Lockheed Martin F-35 Lightning II is a multirole fighter jet that has been one of the most successful fighters in the world.



Is it a plane or a golf ball?

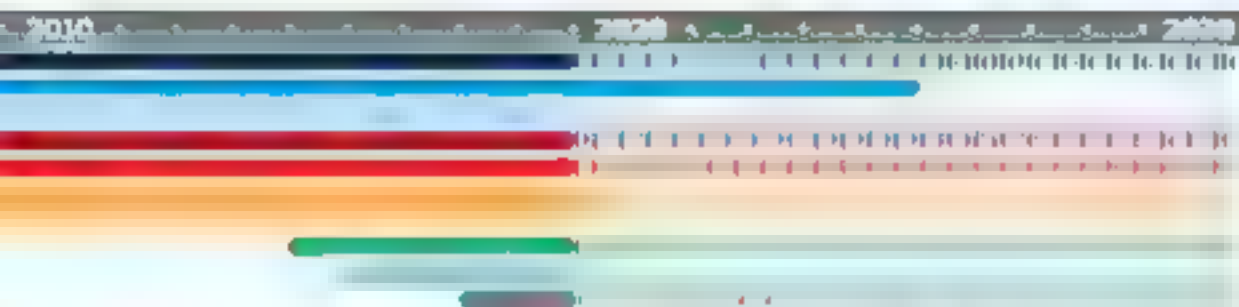
The F-35 is covered in something special: a composite skin machined as accurately as the pieces are virtually seamless on the jet. This completely eliminates any small joining flaws that are detectable by radar.

In the past, stealth aircraft relied on epoxy resin between exterior pieces. Radar is adept at detecting sharp edges. This means it will see any small, sharp edges between panels. Even an expert layer of epoxy will eventually dry, harden and crack, requiring frequent inspections and replacement.

With new technology the panels match so closely there's no sharp edges or epoxy to maintain. As a result the F-35 has very low visibility. If radar catches it at all, what it sees is something more like the size of a golf ball.



The Boeing overhead gantry (H-FGS) machine guides precision machining of the jet's skin.



Subsonic F-35

The F-35 is a subsonic fighter jet. It is designed for low-altitude, high-speed maneuvers. It has a stealthy design and is capable of carrying a large payload of weapons.

Supersonic F-22

The F-22 is a supersonic fighter jet. It is designed for high-speed, high-altitude maneuvers. It has a stealthy design and is capable of carrying a large payload of weapons.

The F-35 is a subsonic fighter jet. It is designed for low-altitude, high-speed maneuvers. It has a stealthy design and is capable of carrying a large payload of weapons.

The F-22 is a supersonic fighter jet. It is designed for high-speed, high-altitude maneuvers. It has a stealthy design and is capable of carrying a large payload of weapons.



SCAN HERE



Inside the F-35B

This short take-off/vertical landing stealth fighter is designed to operate from ship or land

Stealth fibre coating

The aircraft is coated with a special fibre coating that absorbs radar waves, making it almost invisible to radar.

Pratt & Whitney F135 engines

A single engine with a thrust of 23,000 lb (10,400 kg) is used to power the aircraft.

Jet size

Even its jet is smaller than the jet of a standard fighter.



Internal bomb bay

The aircraft has a large internal bomb bay that can hold up to 10,000 lb (4,500 kg) of bombs.

Unmanned air support

The aircraft is equipped with a system that allows it to be controlled remotely by a ground crew.

EDTS - Electro-Optical Targeting System

The EDTS system provides the aircraft with a high-resolution, real-time video feed of the target area.



Lockheed was awarded a contract to develop and build the F-35. After a development and testing period, F-35s were first operational in 2015, and today there are hundreds of these aircraft flying all over the world in wartime operations – and also in air shows.

Called the Lightning II, or just the Lightning for the RAF, there are three types: the F-35A that can land and take off on a conventional runway; the F-35B 'hover' jet; and the F-35C that can be based on aircraft carriers. The F-35 is so flexible and capable that it can be used in just about any environment imaginable.

While the F-35 program is based in the US, more funding comes from allies that work with the US under the North American Treaty Organization, or NATO. These allies include the UK, which plans to buy 138 F-35 aircraft over the life of the programme. So far, the UK has six aircraft – all the F-35B 'hover' variety – stationed at RAF Marham in Norfolk.

British companies are a big part of the F-35 production – including a repair hub run by Seznam Support Services Ltd in North Wales. With so many F-35s projected to operate from the UK, having a repair hub in the country is essential. Otherwise, every maintenance job would require shipping the F-35 across the ocean and back to Lockheed Martin's facility.

British pilots even get their own training. Because all Royal Air Force and Royal Navy F-35



pilots must go through a fast and training facility in Cranwell. The pilots learn how to operate in high g-forces – when forces several times stronger than Earth's gravity push upon them. You can feel this when you push on the bottom end of a roller coaster, and it's the same for a pilot when they dive towards the ground or turn quickly. At Cranwell, the facility can take a pilot up to nine g – nine times Earth's gravity – in only one second.

So what is the F-35 known for, among all the other fighter jets available? The F-35 is built for stealth. The manufacturers must be carefully trained because even small gaps between parts of the fuselage or wings show up clearly on radar. In the past, manufacturers used to put in an epoxy – a sort of glue – to keep everything together. However, the epoxy cracks over time and needs to be repaired. The new process

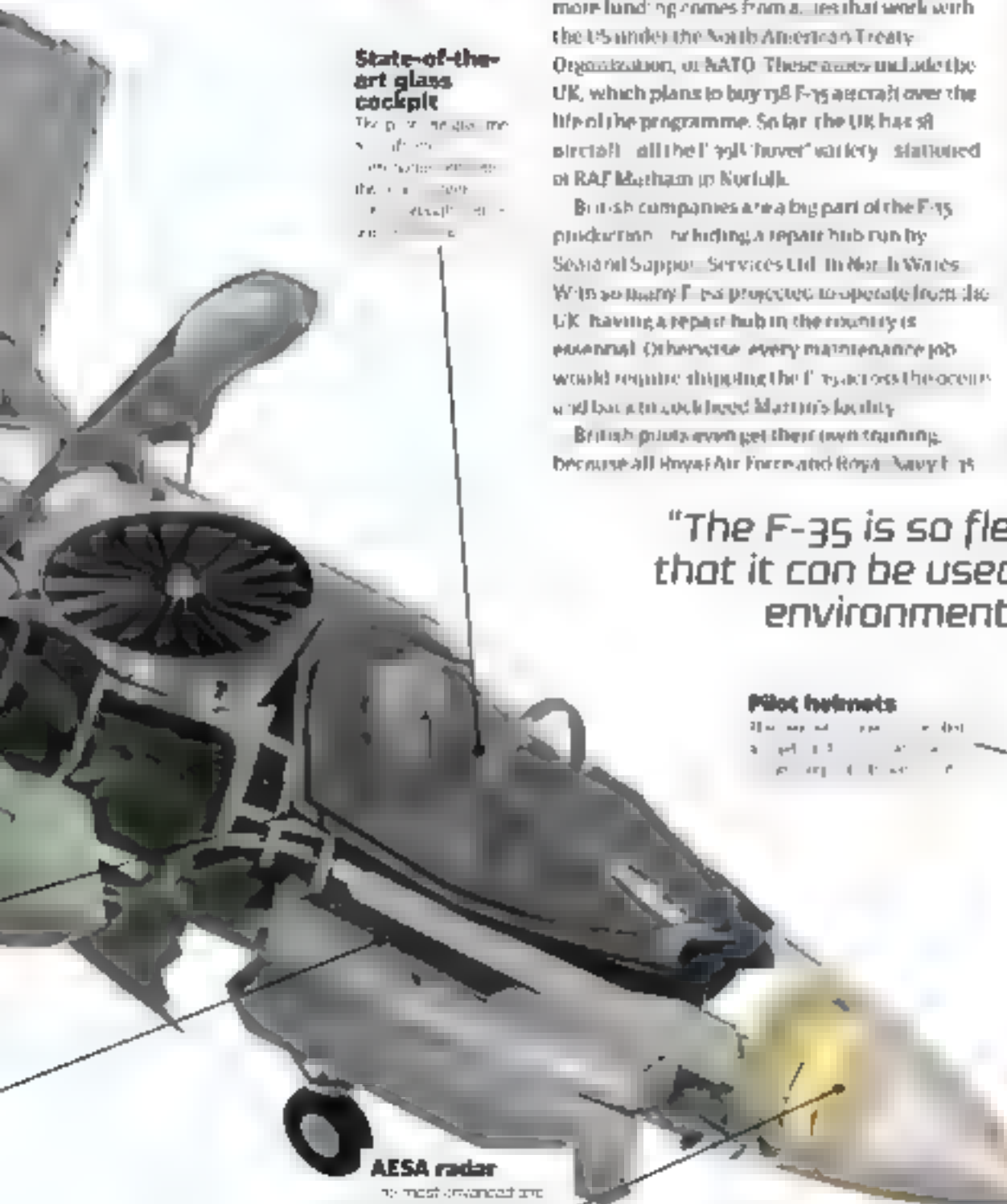
State-of-the-art glass cockpit

The pilot's cockpit is a state-of-the-art glass cockpit. It features a large, multi-touch display that shows the pilot's view of the world around them, as well as various flight data and weapon status.

"The F-35 is so flexible and capable that it can be used in just about any environment imaginable"

Pilot helmets

The pilot's helmet is a state-of-the-art helmet. It features a large, multi-touch display that shows the pilot's view of the world around them, as well as various flight data and weapon status.



AESA radar

The most advanced and largest radar antenna in an aircraft – can scan in any direction.



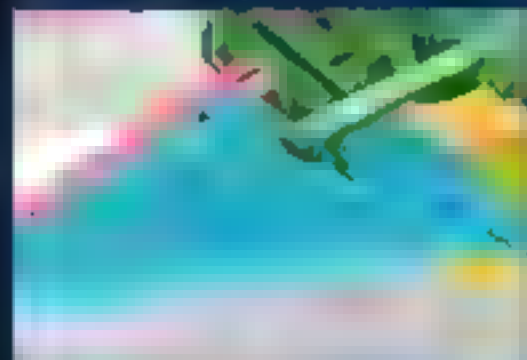
Building the F-35

How the major components of the F-35 come together at the factory



Forward fuselage assembly

The nose and cockpit section are assembled in the forward fuselage section, using precision robotic automation. Parts are staged for inspection.



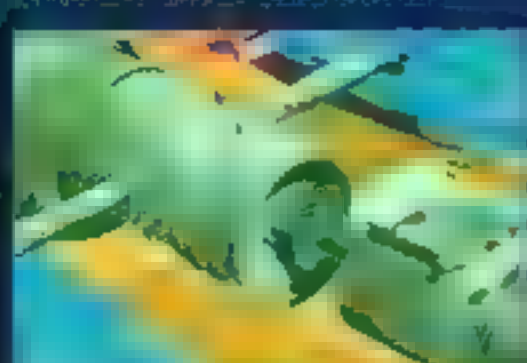
Wing build section

As the largest part of the F-35, the wing is built in a large, curved section. A pulley line is used to move the wing assembly into the factory assembly at each station.



Putting it together

Thousands more and alignment of the aircraft are checked. The final assembly is completed, ready for flight.



Ready to go

At the final assembly, the aircraft is checked, ready for flight. The final assembly is completed, ready for flight.

OGG: HOFER/STARR

425+ 890+ 1

The number of F-35s the factory has produced and delivered to the world's military

How many F-35s have been ordered by the U.S. military

The F-35 is a single-seat stealth fighter jet

"While it feels simple to the pilot, this technology is some of the most challenging engineering undertaken in a stealth fighter"



PHOTOGRAPH BY GUY AROCH

Pilots receive extensive training in simulators that mimic extreme accelerations and high g-forces

8.6 million

F-35 computer systems have as many lines of software code as modern video games

18

The number of hours each F-35 spends in flight

2000

How many flight hours the F-35 has logged in F-35

8

The number of F-35s in the world

F-35 Lightning II

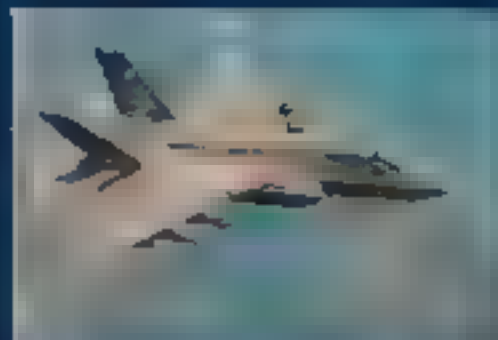
The F-35 is the world's first stealth fighter because of an engine that can swivel 90 degrees during flight.

It is the world's first stealth fighter.



Beast mode

The F-35 can carry 2,500 kilograms of internal weapons in stealth mode, penetrating into enemy territory virtually unnoticed. Once air dominance is established and the skies belong to the F-35, it can head back for restocking. There, it is converted to 'beast mode' without the need for stealth – patrolling with up to 10,000 kilograms of internal and external weaponry. Combining these stealth/beast weapon capabilities with the potential to control drones and robotic wingmen, you can see why the F-35 rules the sky.



The F-35 can carry 2,500 kilograms of internal weapons in stealth mode, penetrating into enemy territory virtually unnoticed.



means the F-35 is built to last and shouldn't need to visit the hangar for repairs quite so often.

If you love video games, the F-35 cockpit is a gamer's dream. The display is so sensitive that very few people know what it looks like. But from what pilots say, it's like playing with the best head-over-shoulder in the days where there were no headsets, but of course, it's not. It could be changed without taking apart the cockpit. The F-35's cockpit is fully electronic, and pilots can call up data they want to see, ignoring the other stuff that isn't necessary for the mission at the time.

Virtual reality fans will also love the helmet, which is a similarly sensitive technology.

Lock head says that pilots wearing this headset can not only view things in front of them, but they can even look at the floor and – thanks to special cameras mounted under the plane – see the terrain whizzing by underneath. No enemy fighters can sneak up on an F-35's belly, that's for sure. If there are friends flying nearby, each pilot's helmet can provide the view the other pilots see as well. So F-35 pilots can help their buddies in combat or see any obstacles that other planes might miss. This enables a whole new era of teamwork.

And speaking of teamwork, an F-35 pilot can also work closely with unmanned drone planes that may be assisting in the mission. Drone

planes are up extremely high to get up close to a target, because if they're shot down, the F-35 pilot can see what's happening and tell the pilot who's who. Not only that, but it can provide guidance as needed. In a not too far future, this will become more common as drone technology improves.

This new era of F-35 isn't only works for today but also a fighter jet of the future. The UK and other military forces around the world hope to use this fighter jet for the next generation, perhaps even up to 2050.

So if you haven't seen one yet, go to your nearest air show and see this futuristic fighter care through the sky for yourself.

Which countries have F-35s?

1. Japan
2. Israel
3. Australia
4. Italy
5. Norway
6. South Korea
7. United Kingdom
8. United States



Q&A

F-35 senior experimental test pilot

We ask Billie Flynn what it's like to be the first to try out Lockheed Martin's new tech

How is flying the F-35 different to other jets you've flown?

Flying in the F-35 is like flying in the most sophisticated virtual reality and video game that ever existed, wearing a helmet like Tony Stark wore in the *Iron Man* and *Avenger* movies. Everything about the F-35 feels like a science fiction fighter jet. Planes before this felt like an old movie. Now, it is like living in a *Star Wars* cockpit.

What hurdles do pilots meet in developing the F-35?

I think the most interesting transition for everyone in the F-35 is to understand that those video game skills – and it terrifies every mother and father when their kids spend more time on video games – are directly applicable to understanding how an F-35 is supposed to be used. We are around our aircraft for hundreds and hundreds of kilometres in all directions. Our touchscreen LCD displays are filled with the most sophisticated information. Someone who is skilled at video games will adapt to that level of sophistication and complexity far better than an older generation of pilots.

How adaptable is the F-35 to the technologies of the future?

We are at the beginning of a lifetime that will last 40 to 50 years. We're going to expect our F-35 to evolve, to do so many things differently in the air and on the ground – and for our troops – than we ever thought imaginable at the beginning of its lifetime. We have an extraordinary cockpit, with an aircraft powered by 8.6 million lines of software code, just in the beginning of its lifetime. We can adapt over the coming generations to do things we never thought possible when we first... designed the plane.

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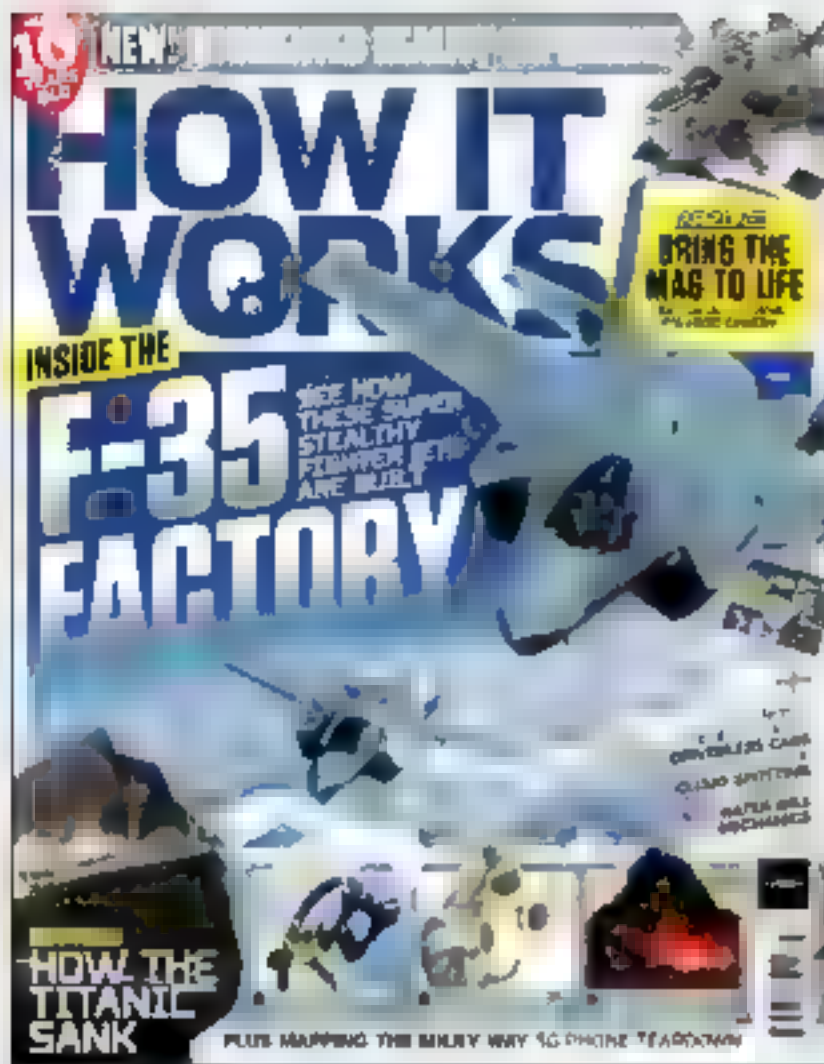
Foreword by Robert
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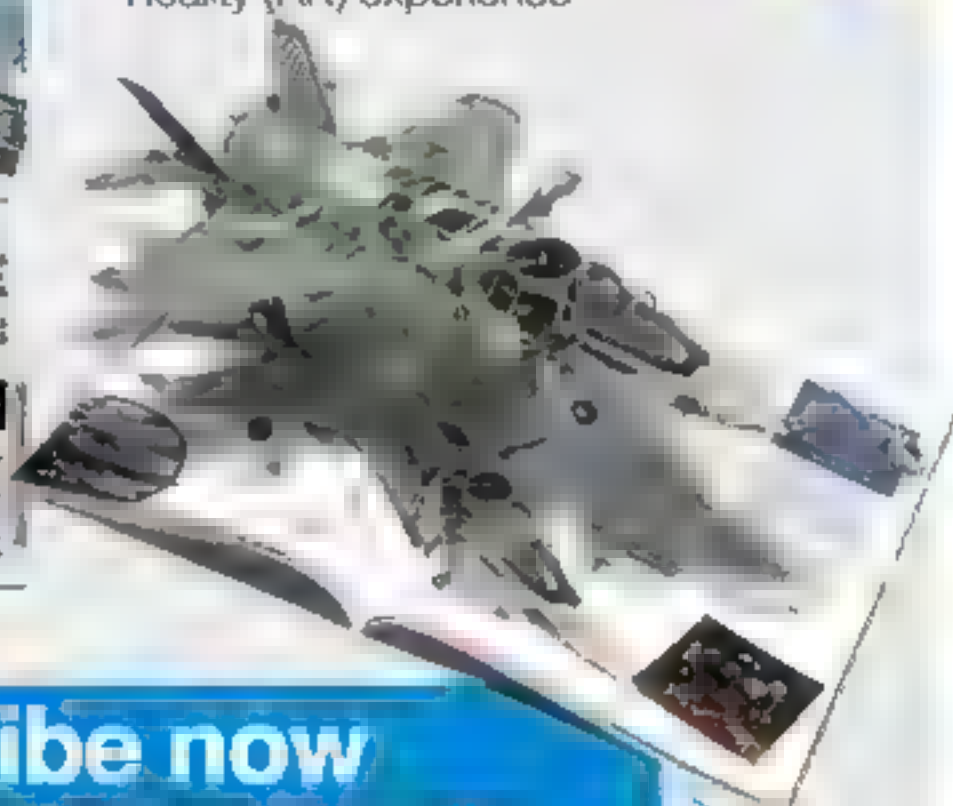
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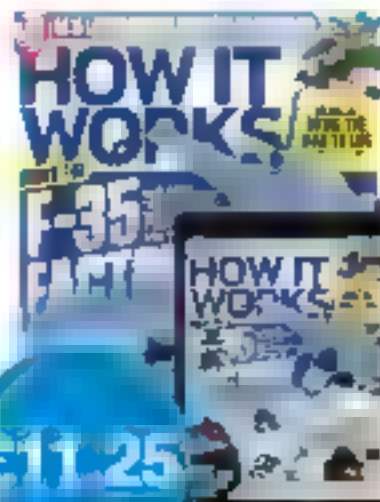
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THE MAGIC OF CARBON CHEMISTRY

Discover how this protean wonder-element can make more than 9 million different chemical compounds

Words by Laura Meacham

Carbon is so versatile and so important that the Royal Society of Chemistry calls it the 'King of the elements'. It's everywhere, and we use it for everything. Carbon sits at position six on the periodic table. It has six protons, six neutrons and six electrons. Two of those electrons fill up an electron shell close to the nucleus, while the other four sit in a half-empty shell around the outside. These outer electrons, known as the valence electrons, are the key to carbon's incredible properties.

The electrons in an atom's outer shell are the ones that take part in chemical bonds. How many bonds depends on how much space there is in the shell, and the amazing thing about carbon is that it's got space for

four. This means that it acts like a plumbing cross-piece, becoming a four-way connector that links different atoms together. It can build straight chains, chains with branches, and chains joined end to end to make loops. And it doesn't just bond to itself. The edges of carbon chains can terminate in tiny hydrogen atoms, making them slippery like oil, or they can connect to other groups of elements, called 'functional groups', each of which has different chemical properties.

Carbon works like elemental scaffolding, and the shapes, sizes and chemistry of the molecules it creates vary enormously.

Another important feature of carbon is that, although the bonds it makes are strong, they're not unbreakable. Carbon-based



molecules are stable enough that they won't fall apart, but given the right amount of energy, they can be reworked into something new. This makes carbon the perfect backbone for the molecules of life. Fats, carbohydrates, proteins and nucleic acids (DNA and RNA) are all built around carbon.

There are 100 million billion metric tons of carbon on Earth today and it's all been around longer than the Solar System. Our Sun is the grandchild of the very first stars in the universe—it was born about 4.6 billion years ago out of a cloud of dust and gas created by a supernova explosion. That dust and gas contained every element, carbon on our planet, and more.

Carbon reacts with oxygen to make the infamous trapping gas—carbon dioxide. Too much can cause a runaway greenhouse effect that makes planets impossible to inhabit (just look at Venus—its surface temperature is 460 degrees Celsius).

Lucky, Earth didn't become a greenhouse.



ocean or atmosphere for carbon-based life. And in a strange way, life and Earth have been working together to keep it that way ever since. Carbon is Earth's thermostat.

Earth has a slow carbon cycle on a 100-million-year scale. In carbon dioxide in the atmosphere reacts with water to make carbonic acid, which eats away at the rocks. This releases trapped calcium. Shell-making organisms in Earth's oceans combine that calcium with carbon-containing ions to make calcium carbonate. When they die and drop to the sea floor, their remains become sediment, locking carbon away underground. Slowly, this carbon returns to the atmosphere as Earth cracks, shrinks and shakes. Volcanoes do this too, the rocks and releases carbon back into the air at a rate of around 30 to 350 million metric tons every year.

Layered over the slow cycle is a fast carbon cycle, governed by plants. They take in carbon dioxide and use energy from sunlight to trap carbon in organic molecules. Those molecules then pass through the food chain, becoming

"Carbon is a four-way connector that links different atoms together"

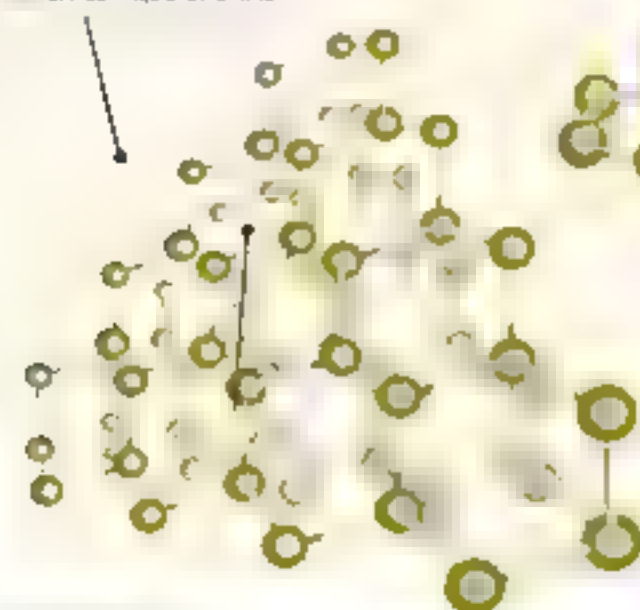


Kinds of carbon

This versatile element comes in a variety of forms called allotropes.

Diamond

In carbon as a diamond, four four-carbon rings are joined together in a 3D cube of six atoms.



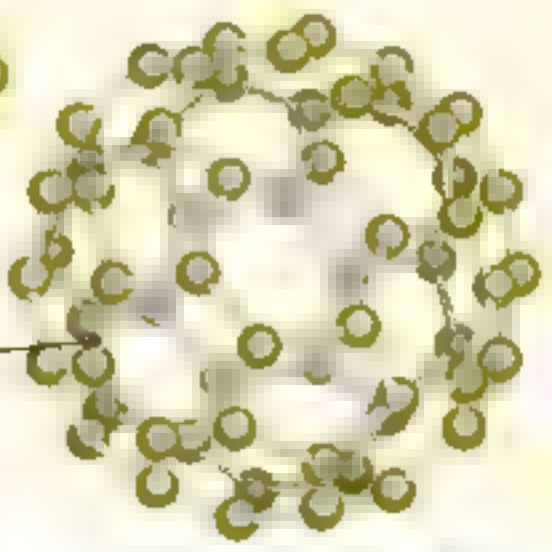
Graphite

A single layer of carbon atoms, graphite is a good conductor of electricity. It is used in pencils and as a lubricant.



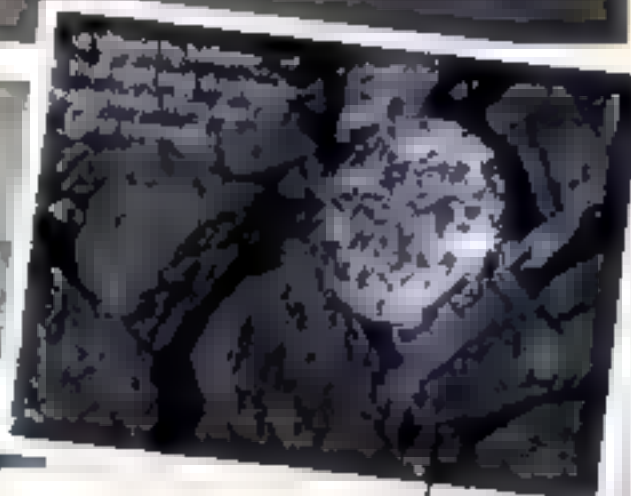
Buckminsterfullerene

A molecule of 60 carbon atoms, buckminsterfullerene is a spherical molecule that can be used in nanotechnology.





Radio carbon dating uses the decay of carbon-14 to assess the age of organic material



Amorphous

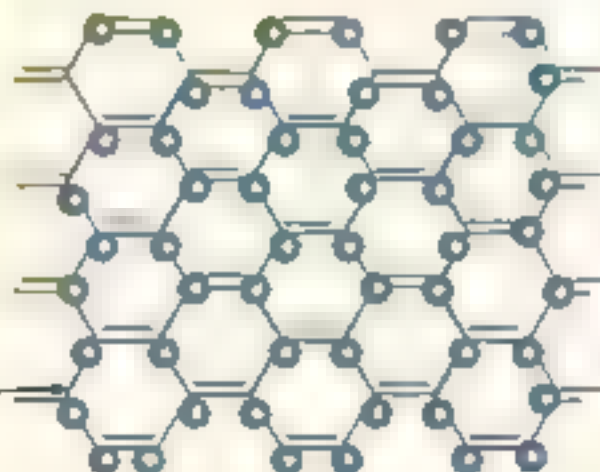
Carbon is a very hard material. It is made up of many small particles that are not arranged in a regular pattern. This makes it very strong and resistant to wear.

Nanotube

Carbon nanotubes are made of a single layer of carbon atoms. They are very strong and flexible, and they can be used in many different ways.

Graphene

Graphene is a single layer of carbon atoms. It is the strongest material ever made, and it is also very flexible. It has many uses in industry, including in electronics and in the construction of aircraft.



CHEMICAL COMPOSITION

The human body is made up of these vital elements



Cosmic rays

Cosmic rays are high-energy particles that come from outer space. They can be made of protons, neutrons, or electrons. When they hit the Earth, they can create other particles, like nitrogen-14.

Nitrogen-14

Nitrogen-14 is a stable isotope of nitrogen. It is made up of 7 protons and 7 neutrons. It is the most common form of nitrogen on Earth.

Food chain

A food chain is a series of organisms that eat each other. It shows how energy flows from one organism to another. In this example, the tree is eaten by the cow, which is then eaten by the tiger.

Start the clock

When a cosmic ray hits a nitrogen-14 atom, it can change it into a radioactive isotope. This is the start of the clock.

Ticking clock

As the radioactive isotope decays, it releases energy. This energy can be measured and used to determine the age of the sample.

Stop the clock

When the radioactive isotope has decayed completely, the clock stops. This is the end of the measurement.

Radioactive decay

Radioactive decay is the process by which a radioactive isotope loses energy. This can happen in different ways, such as by emitting alpha or beta particles.

Inside a bionic heart

Swapping muscle for metal, how does this artificial organ keep blood flowing?

Cardiovascular disease is one of the world's biggest killers, accounting for 31 per cent of all deaths globally. Although a lot of cases are treatable with a heart transplant, findings don't seem to be coming in fast enough. Half of over 4,000 hearts are available globally each year.

The creation of a metal artificial heart (TAH) could be revolutionary for saving lives. Several iterations have been tried over the past few decades, but none have had the ability to completely copy the heart's function for more than a few years.

The latest and arguably most promising development of a TAH comes in the form of the BIVACOR, a 3D-printed titanium pump that utilizes an extraordinary magnetic rotor to circulate blood.

One of the common issues found in previous TAH technology has been the physical wear and tear of a device's moving parts. Using magnetic levitation (maglev), the BIVACOR's central spinning rotor is magnetically suspended inside an electromagnetic field. As electricity passes through, it magnetizes the rotor spine, propelling

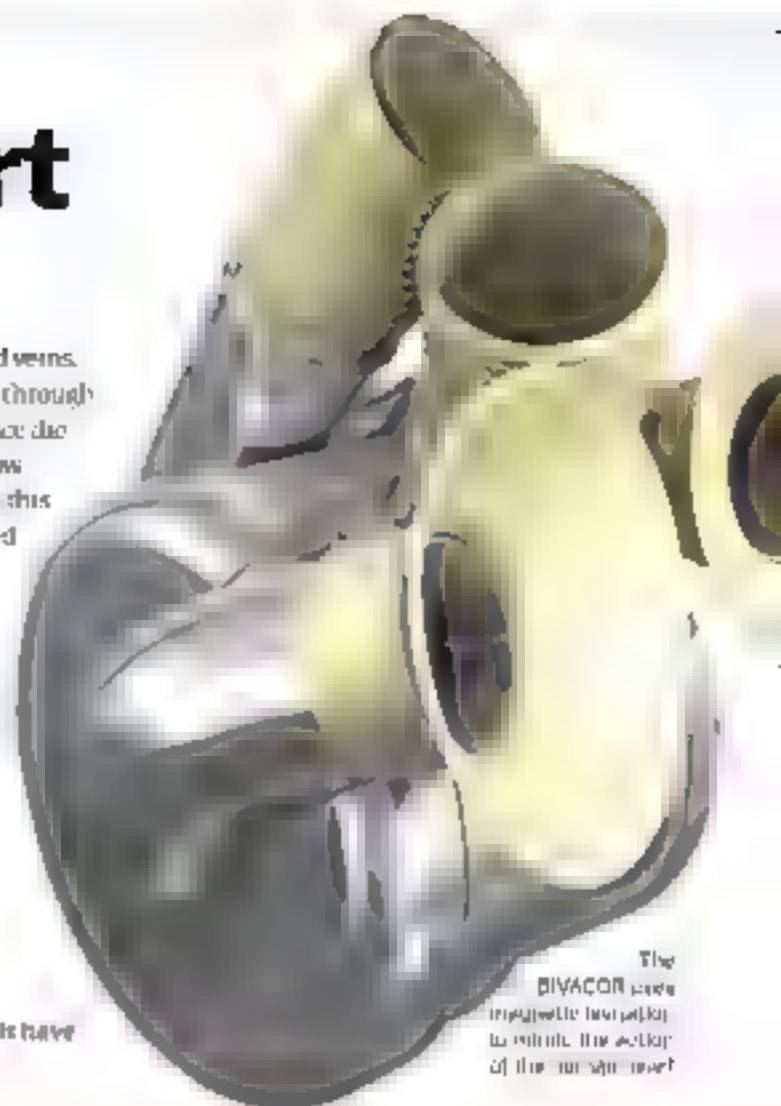
the blade around the body's arteries and veins. Maglev prevents physical wear and tear through normal friction, and it is thought to reduce the complications that would normally follow.

"The rotor spins, propelling the blood around the body's arteries and veins"

Smaller than a can of coke, this compact device is constructed using a form of metal 3D printing called selective laser sintering (SLS). This process involves repeated layers of fine titanium dust being melted by a laser to slowly print the final form.

The BIVACOR has shown promising results during its animal trials, with bovine pump subjects surviving the full 90-day test period.

However, the device is still in its development stages, and no human trials have been carried out so far.



The BIVACOR uses magnetic levitation to mimic the action of the human heart

Inside an artificial heart

Discover how BIVACOR uses magnets to ferry blood cells around the body

'Right atrium'

On the right side of the heart, the right atrium receives blood from the body and pumps it into the right ventricle.

Magnetic bearing

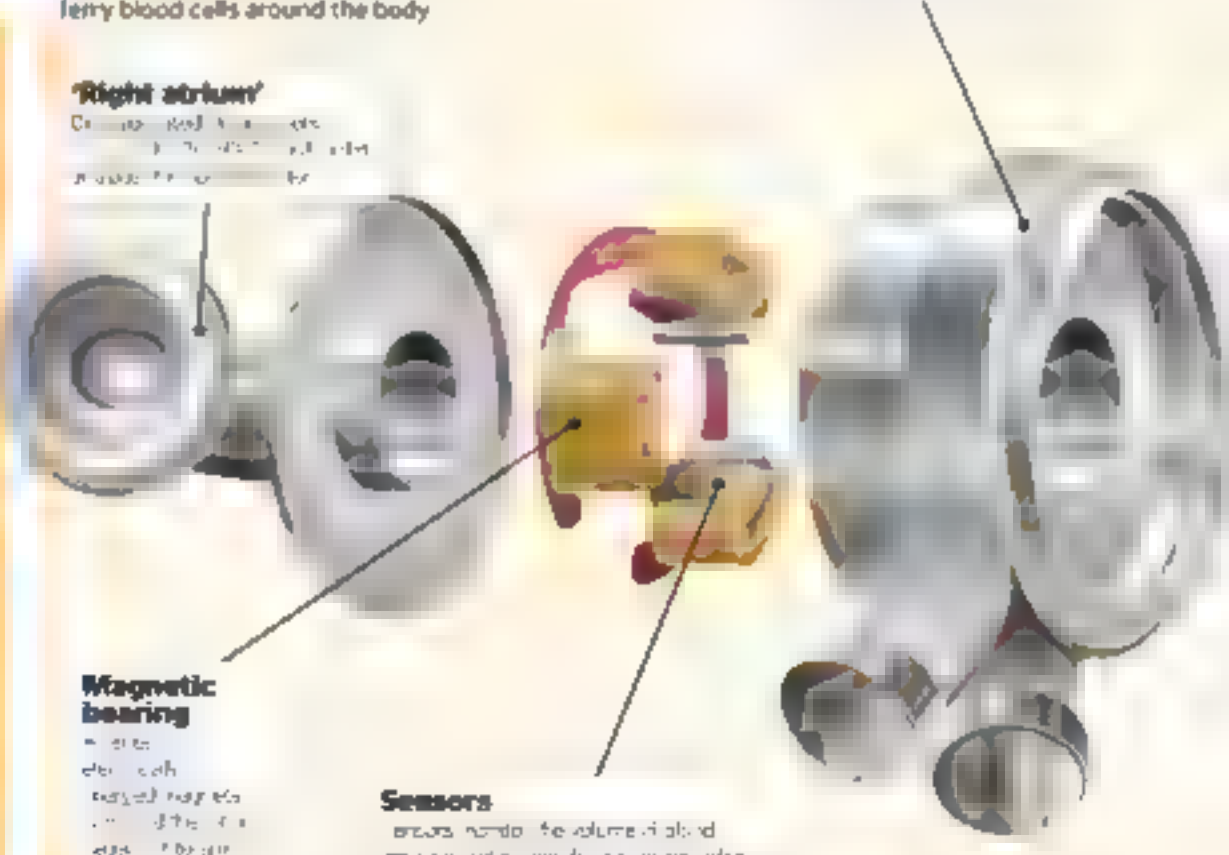
The magnetic bearing is a key component of the BIVACOR, allowing the rotor to spin freely without physical contact.

Sensors

The BIVACOR features sensors that monitor the volume of blood entering and leaving the device, as well as the pressure within the chambers.

'Aorta'

The aorta is the main artery that carries blood from the heart to the rest of the body.





TITANIC

HOW THE 'UNSYNKABLE' SHIP SANK



"I cannot imagine any condition which would cause a ship to founder"

because it was built to stay afloat even with major flooding. But this unsinkable ship would go down – both in the ocean and history.

On any one evening of 12 April 1912 and the morning of 15 April 1912, just four days after setting off, *Titanic* sank. Two hours and 40 minutes after hitting an iceberg, the ship lay in pieces below the surface of the Atlantic.

Some passengers had always doubted its safety, but other people died because they refused to leave on lifeboats, clinging to the ship because, *the world's safest ship* after all. Why would you voluntarily enter treacherous waters when you're on a ship you've been assured could never sink?

The captain usually towed the ship's proud confidence held by most in shipboard danger the same. Before his first voyage he said, "I cannot imagine any condition which would cause a ship to founder. I cannot conceive of any disaster happening. Modern shipbuilding has gone beyond that."

Until 7 May 1912 the disaster raised many questions about what was and was not done at the time. Every action taken that night has since been analysed and re-analysed during inquiries. The wreckage, which still lies below the water, has been inspected in order to pinpoint where exactly the disaster laid. How could this tragedy have been prevented?



Titanic's boiler room deck was nearly 20 metres from the water line



14 April

8:20pm

Titanic sailed from Southampton with a full complement of passengers and crew.

10:55pm

A iceberg was sighted by a lookout on the ship's crow's nest. The ship's captain ordered the ship to turn to starboard.

11:00pm

A iceberg was sighted by a lookout on the ship's crow's nest. The ship's captain ordered the ship to turn to starboard.

11:30pm

The ship's captain ordered the ship to turn to starboard. The ship's captain ordered the ship to turn to starboard.

11:35pm

The ship's captain ordered the ship to turn to starboard. The ship's captain ordered the ship to turn to starboard.

Fighting the flood

Engine rooms were flooded into the ship, above-deck passengers faced darkness, oblivious to the damage.

The first act

A iceberg was sighted by a lookout on the ship's crow's nest. The ship's captain ordered the ship to turn to starboard.

Darkness under deck

When water started rising in the engine room, the ship's captain ordered the ship to turn to starboard.

The first cracks

The ship's captain ordered the ship to turn to starboard. The ship's captain ordered the ship to turn to starboard.



DID YOU KNOW? Titanic had a carrying capacity of 46,328 tons, and ended up displacing more than 52,000 tons



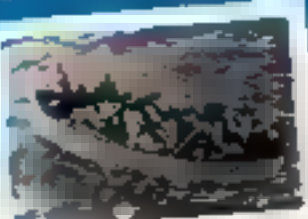
Evacuation

After the collision, the ship was evacuated. The evacuation was a chaotic scene, with many people struggling to get to the lifeboats. The ship's crew and passengers were in a state of panic, and the evacuation was a desperate race against time.

The iceberg caused multiple slashes in Titanic's hull, flooding five compartments

Stop

The ship's engines were stopped, and the ship began to list. The ship's crew and passengers were in a state of panic, and the evacuation was a desperate race against time.



15 April

11:40pm

First officer William Murdoch orders engineer to reverse the engines. The ship begins to slow down, but it is too late to avoid the iceberg.

11:50pm

The ship strikes the iceberg, causing multiple slashes in the hull. The ship begins to list, and the evacuation begins.

12:00am

The ship's engines are stopped, and the ship begins to list. The ship's crew and passengers are in a state of panic, and the evacuation is a desperate race against time.

12:05am

The ship's engines are stopped, and the ship begins to list. The ship's crew and passengers are in a state of panic, and the evacuation is a desperate race against time.

12:20am

The ship's engines are stopped, and the ship begins to list. The ship's crew and passengers are in a state of panic, and the evacuation is a desperate race against time.

12:20am

The ship's engines are stopped, and the ship begins to list. The ship's crew and passengers are in a state of panic, and the evacuation is a desperate race against time.

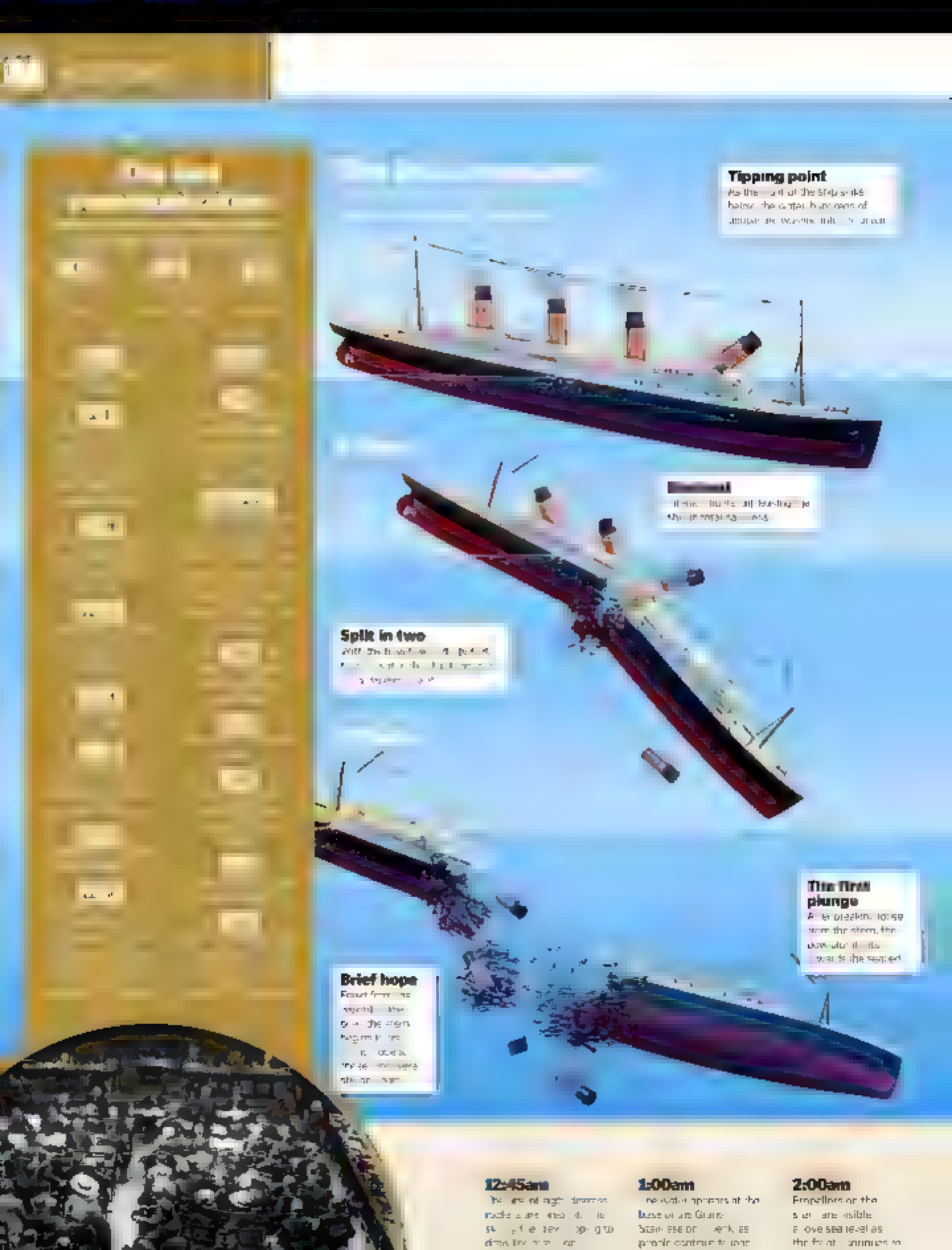


How the water spread

After colliding with the iceberg, the front of the ocean liner suffered damage and five of its 16 compartments ruptured. The ship was designed to stay afloat with 12 of its compartments intact, but with only 11 holding the ship together. It wasn't long before the flooded front began to pull the bow of the ship downwards.

The design included a series of emergency doors that would close to prevent water spreading. However, the bulkheads, which were watertight walls separating the compartments, weren't tall enough, and the water swiftly spilled over the top.

Scientists later discovered that a series of thin gashes inflicted on the hull by the iceberg allowed water to stream into the ship, rather than one large slash as was originally believed. It is speculated that the poor quality of the steel used in rivets holding the hull together contributed to Titanic's rapid demise.



Tipping point

As the front of the ship sinks below the water, hundreds of Atlantic Ocean liner passengers

Three hours of boarding to the ship was over

Split in two

With the bow down, the ship split in two, with the stern section rising

The final plunge

After breaking 10:58 from the stern, the bow of the ship was the last to

Brief hope

From the bow, the ship was seen to be the stern, the bow of the ship was seen to be the stern, the bow of the ship was seen to be the stern

12:45am

The first sight of the ship was seen to be the stern, the bow of the ship was seen to be the stern, the bow of the ship was seen to be the stern

1:00am

The ship was seen to be the stern, the bow of the ship was seen to be the stern, the bow of the ship was seen to be the stern

2:00am

The ship was seen to be the stern, the bow of the ship was seen to be the stern, the bow of the ship was seen to be the stern



Standing vertical

Bow of the ship is the part of the ship that is still standing upright. It is the part of the ship that is still standing upright.

Vanishing beneath

The ship's hull is the part of the ship that is still standing upright. It is the part of the ship that is still standing upright.

Laid to rest

The ship's hull is the part of the ship that is still standing upright. It is the part of the ship that is still standing upright.

2:17am

The ship believes the last few minutes of their lives. The ship believes the last few minutes of their lives.

2:20am

The ship believes the last few minutes of their lives. The ship believes the last few minutes of their lives.

3:30am

The ship believes the last few minutes of their lives. The ship believes the last few minutes of their lives.

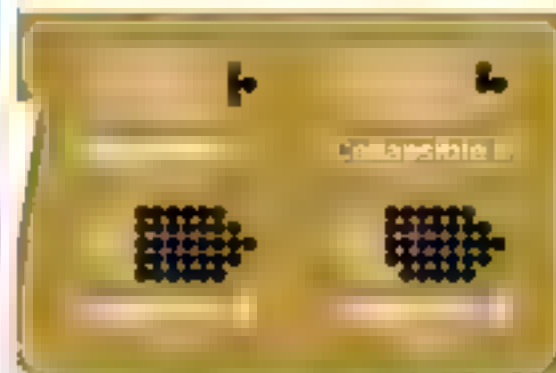


Lacking lifeboats

Titanic had 20 lifeboats to carry 1,178 of the 2,200 people. A lifeboat drill due that day was cancelled, and in a disorderly process boats left half-empty. Only 705 escaped in those boats.

KEY

Time: 10:00 11:00 12:00



Meet Stephenson's Rocket

Discover the single most important object in the modern age and meet the humble makers who built the modern world from their kitchen tables in Brass, Steel and Fire at the National Railway Museum

Built in 1825 by English locomotive manufacturers Robert Stephenson and company, *Hickins* has become one of the UK's most historically significant objects. It achieved a then-remarkable top speed of 48 kilometres per hour, winning the contract for the company to produce locomotives for the railway and securing its place in history. The only one operated on the world's first inter-city passenger railway in 1825, ushering in the railway age.

This bold prototype changed the course of history with its experimental engineering. Through the Brass, Steel and Fire exhibition you will meet the ordinary people who, inspired by Stephenson's *Rocket*, transformed their kitchen into makeshift workshops and created extraordinary machines entirely from scratch. Vintners, ice makers and furniture breeders became tinkering, steaming, brilliant locomotive makers in their workshops built inside their homes. Discover their heartily intimate homemade creations,

including some of the ideas of their mind. Learn how their small-scale experiments pushed the boundaries of engineering, accelerating the course of the Industrial Revolution. And for the first time in 20 years, you'll have a chance to see the world-changing locomotive that kickstarted a golden era of innovation. In addition, as *Rocket* travels to York to complete the final leg of a national tour of UK museums, organised by the Science Museum Group.



A photograph of Robert Stephenson, taken 2 years after his *Rocket* success.



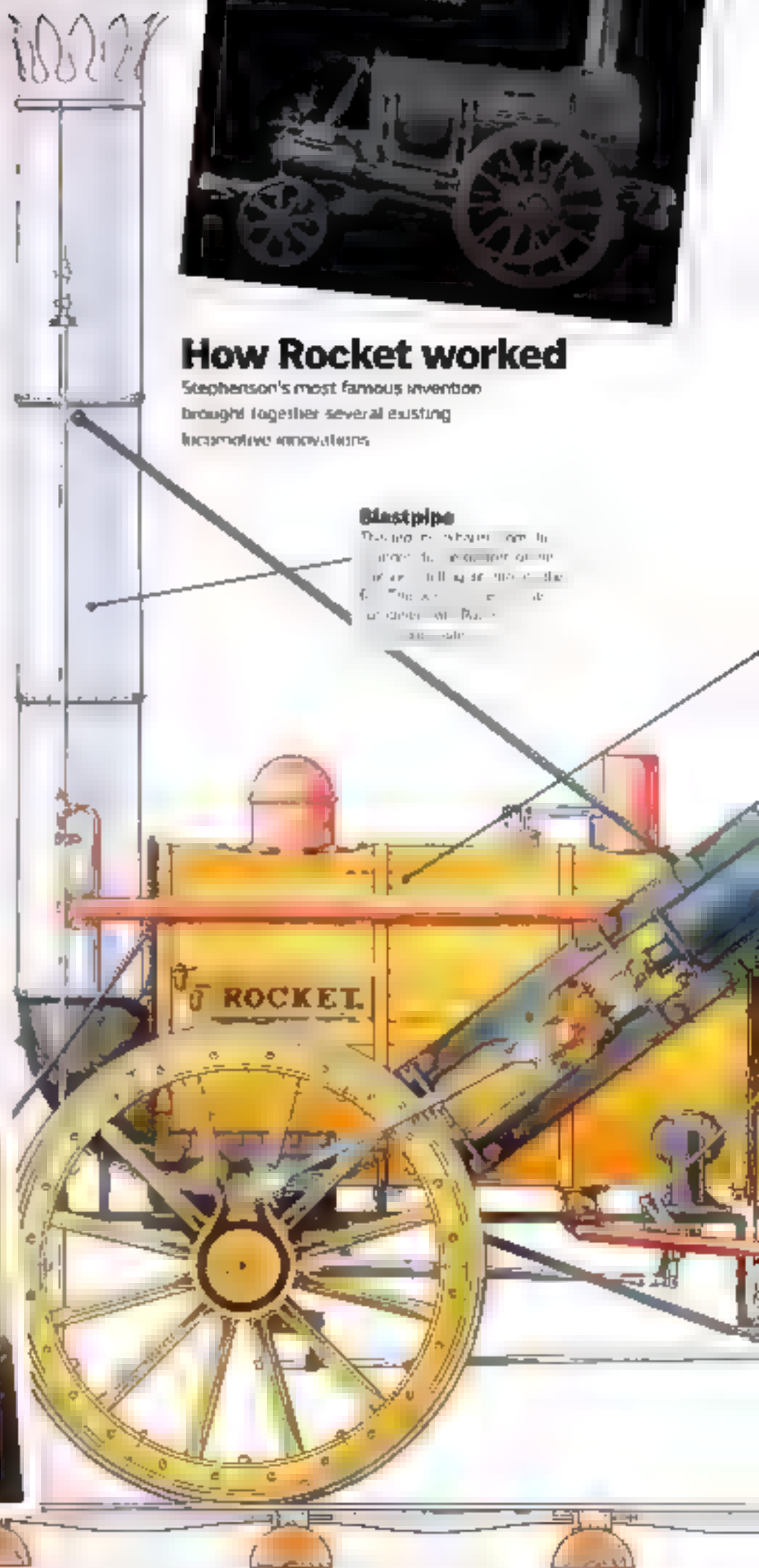
The *Rocket* appeared on the track at the old 1825 to 2012, from 1825 to 2012.

How *Rocket* worked

Stephenson's most famous invention brought together several existing locomotive innovations

Blastpipe

The blastpipe is a pipe that carries the exhaust steam from the cylinders to the chimney. It is a key component of the locomotive's exhaust system.



DID YOU KNOW? Some Victorians believed humans would suffocate on a train travelling over 48kph from the rushing wind

Arthur Peasey's idea for a locomotive that ran on air was ahead of its time. Instead of steam, his demonstration model was powered by compressed air from an copper tanks.



This quirky 1820s model steam engine was redesigned again and again by engineer Simon Goodrich as he experimented with the latest in railway developments.



Multi-tube boiler

Rocket had 5 water tubes for heating the boiler. This was a significant improvement on the previous locomotives which had only one tube.

See the original Rocket in all its restored glory in Brass, Steel and Fire at the National Railway Museum, from now until 13 April 2020

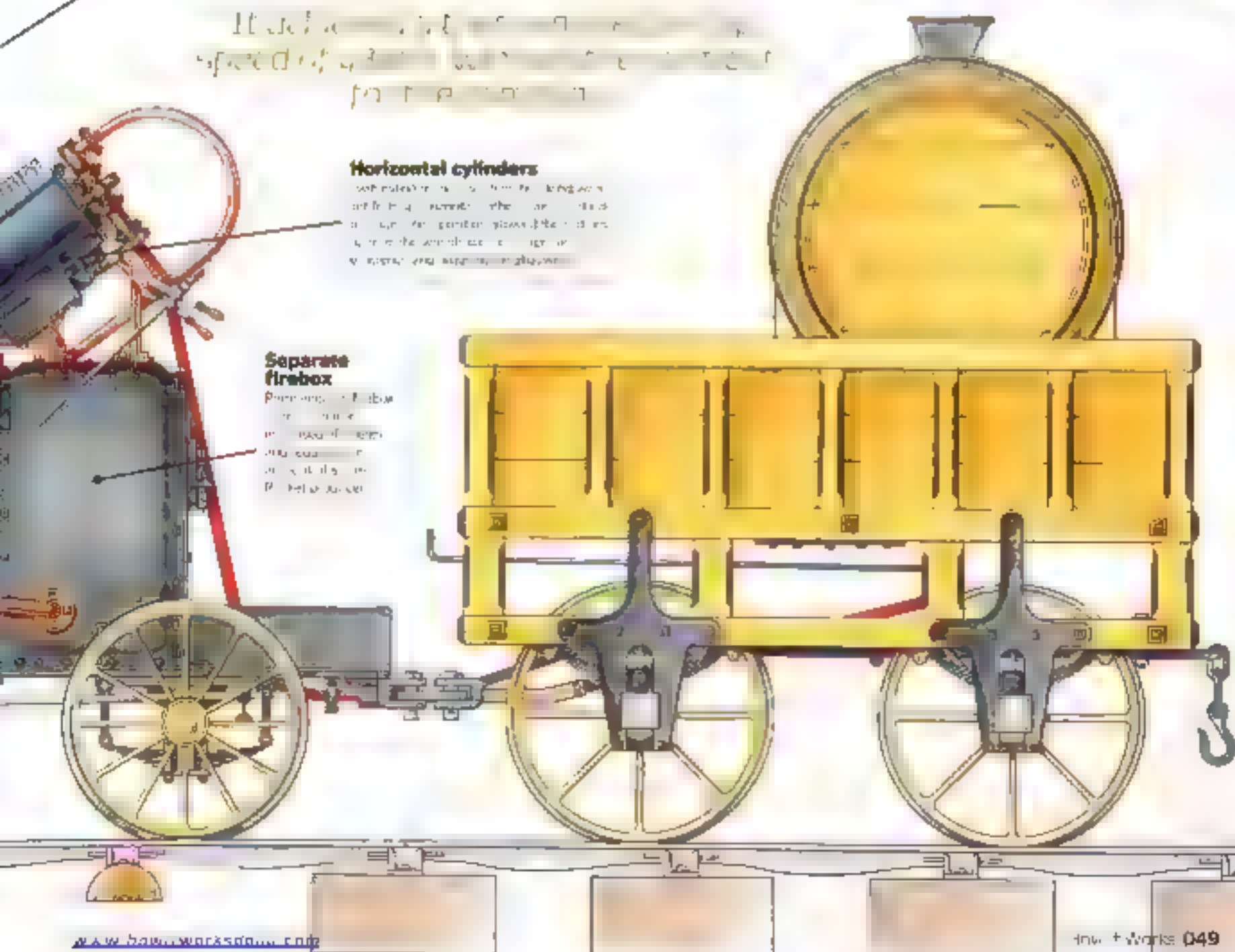
It was a significant improvement on the previous locomotives which had only one tube.

Horizontal cylinders

With multiple cylinders, the locomotive could run at a faster speed. The cylinders were also horizontal, which allowed for a more compact design.

Separate firebox

Previously, the firebox was attached to the boiler. This design allowed for a more efficient combustion process.



Water mill power houses

This simple mechanism uses flowing water to reduce the need for manual labour

Looking at the man-made objects that surround you, how many have been made completely by hand? The answer is probably not many. Before water mills were invented, every step in production involved manual labour. Water mills provided the first power for man that didn't require animals or humans to produce.

Using a water wheel placed in flowing water, kinetic energy is able to create a consistent mechanical energy. The combination of the wheel and the machinery attached to it is a water mill.

The mechanical output from these structures greatly benefited communities by carrying out jobs such as driving saw mills, grinding corn and flour, moving pumps, making vegetable oils and powering textile mills. For centuries, flour was a staple food and in high demand, so this production method has helped to feed society ever since. Run into the modern period.

The wheel at work

How did this early hydropower source operate?

Pushing the wheel

The water flowing over the wheel pushes it. As the wheel turns, the machinery attached to it is able to perform the work that the water is doing.

Water release

The water is released from the top of the wheel and back into the river for a sustainable system.

Different countries developed the system for different purposes. While Greek mills were used to grind grain, many Syrian mills were used for converting cotton into cloth. For these textile mills, which appeared in France during the 17th century, the water's motion was used to lift wooden hammers that beat the cloth.

These simple energy uses came before the arrival of steam power or electricity. In the early 20th century, similar principles were used to produce sustainable electrical energy. The invention of the water turbine means that in developed countries, water mills were no longer as useful. However, there are still over 20,000 operating in Nepal and approximately 200,000 in India, where they are often used for processing grain.

Directing water

The water is directed into the wheel by a channel or race. The water flows over the wheel and is released back into the river.

Constant rotation

The constant rotation of the wheel enables the mechanical energy to be used to grind grain and other materials.

Turning the cogs

The cogs of the wheel are used to turn the machinery that is attached to the wheel.

Moving the machinery

The machinery is moved by the water and is used to grind grain and other materials.

Harry Potter

WIZARD'S
WORLD

STEP ABOARD

it is going to be a bump ride!



As seen in Harry Potter and
the Prisoner of Azkaban



"The iconic locomotive from
the Harry Potter series"



EVEN MORE MAGIC

for your collection



"As introduced in Harry Potter and
the Chamber of Secrets"

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1:43



Water jet-powered flight

How do these jet ski accessories use water to keep you airborne?

There could be some time to wait before we are commuting to work by jetpack or hopping on a hoverboard to go shopping, but hydroflight is giving us a glimpse into the future of flying transport.

Ditching the concept of the combustion engine for water power, hydroflight jetpacks and flyboards are firing people up in the air, albeit while tethered to a motor. The principle of hydroflight involves using a jet ski or personal watercraft (PWC) to generate enough force through a connecting pipe to lift a person out of the water.

When the operator turns on the jet ski's throttle it causes the motorised blades beneath to accelerate. This 'impeller' sucks

up large amounts of water from the body of water the PWC sits on, and pumps it out the other side. The expulsion of water generates enough force to move the jet ski forward.

When that expelled water is pumped into a hose rather than back into the ocean, that generated force flows through the hose, leaving the jet ski stationary. By placing a jetpack at the end of the hose and directing

the release of water downwards, a pilot can utilise the generated force to fly in the air.

The first hydroflight jetpack, JetLev, came from inventor Raymond Li in 2009. He initially attempted to house a motor capable of generating enough thrust on his back, but it wasn't until he outsourced that task to a PWC that his invention really took off. Li and his JetLev rose from the water's surface, starting a whole new industry that has expanded enormously since then.

Now a common sight at many popular holiday destinations around the world, hydroflight has diversified from the jetpack design into flyboards and even into flying jet skis.

"Directing the release of water downwards, a pilot can utilise the generated force to fly"

Participants of Flyboard World Championships celebrate water sports festival in Hugging, UK



Connection

Water is pumped to the flyboard and then a small hole in the middle of the hose causes the water to be forced through the impeller and out.

Impeller

The impeller is a small, circular, rotating blade that is used to pump water through the hose and out of the flyboard.

Flyboards use the force of the water to propel them upwards.



www.hydroflight.com

DID YOU KNOW? Polaroids brought smiles to photographs. Before, long exposure times meant most subjects didn't smile.

Lighten/darken control

Lighten/darken control on the shutter in the camera's aperture. When the shutter is open, the aperture is open.

Life magazine's cover from 1972 depicts the fascination shown towards John's invention.



Closing the shutters on Polaroid

Polaroid's first camera was sold for \$6 years. The company's first camera was sold for \$6 years. The company's first camera was sold for \$6 years.

The shift of photography from film to digital reduced consumer demand for Polaroid cameras. The company decided to stop manufacturing them. However, there were still people buying them.

However, Polaroid's reputation for quality cameras was still strong. The company decided to stop manufacturing them. However, there were still people buying them.

Photocell

The photocell is a light-sensitive device that controls the camera's shutter. It is a small, rectangular device that is mounted on the camera's body.

Four-element lens

The four-element lens is a complex optical system that allows the camera to focus light onto the film. It consists of four glass elements that are precisely aligned.

Two-bladed electronic shutter

The two-bladed electronic shutter is a device that controls the exposure time. It consists of two blades that move in and out of the light path to expose the film.

Fresnel surface

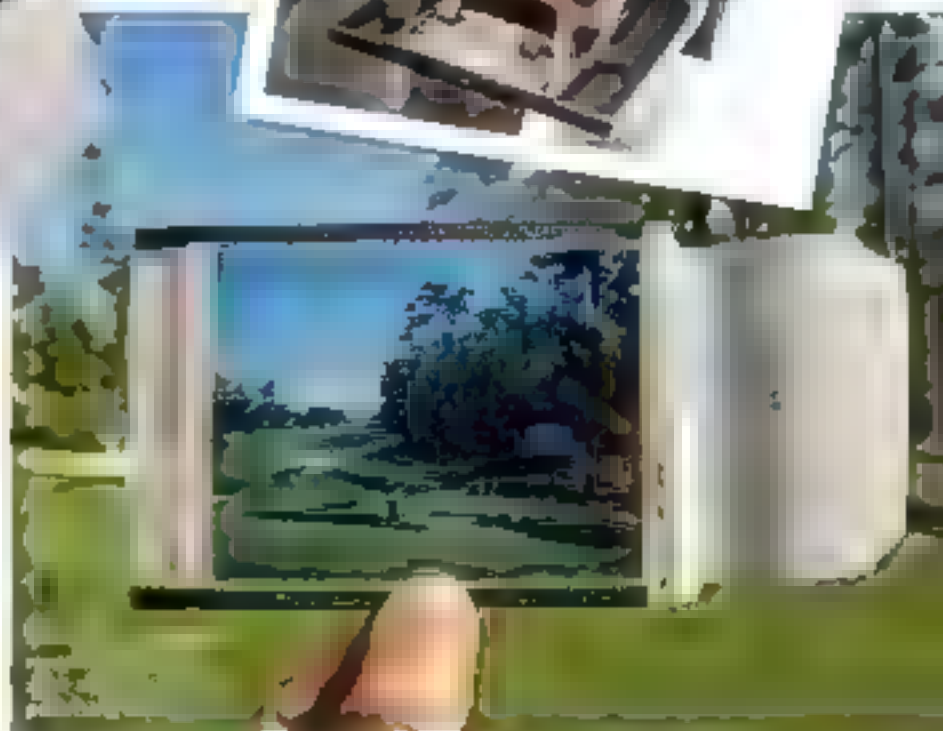
The Fresnel surface is a series of concentric rings that help to focus light. It is a key component of the camera's lens system.

Processing rollers

The processing rollers are used to move the film through the development process. They are located inside the camera's body.

Developing picture

The developing picture is the final stage of the Polaroid process. It involves the film being exposed to light and then developing into a visible image.





Inside the Huawei Mate 20 X 5G

Take a look under the bonnet of one of the new 5G smartphones

Huawei is leading the way in 5G, not just because the Chinese company has created much of the technology used in the world's 5G rollout. The tech giant has also started pushing 5G phones into the hands of customers across the country—and this is one of the first. The Huawei Mate 20 X 5G model is a must-identify to the standard Mate 20 X, but with one important difference. It can take advantage of the new, faster 5G network.

The phone is powered by the Balong 5000, Huawei's first seven-nanometre 5G chipset. It supports both the non-standalone (NSA) and standalone (SA) 5G architectures, which means it can get better speeds today, and will go even faster once coverage of the UK network improves.

That, of course, is the big news here. But the phone has plenty of other tricks up its sleeve. The 7.2-inch OLED screen goes from edge to edge, with only the smallest notch at the top of the screen for the camera. Inside, you'll find a 4,000mAh battery that you can power up in just a few minutes using one of Huawei's special high-speed chargers.

On the back, you'll find a triple-lens camera. The main camera is 40MP, allowing you to capture incredible details, while an HMIR camera with a telephoto zoom lens will help you capture distant scenes. Finally, the 20MP camera gives you an ultra-wide-angle lens, so you can take incredible landscape photos and awesome macro shots.

Huawei's 5G model will bring faster internet speeds to your smartphone

How a 5G phone works

A surprisingly small number of components go into this superfast device

The screen

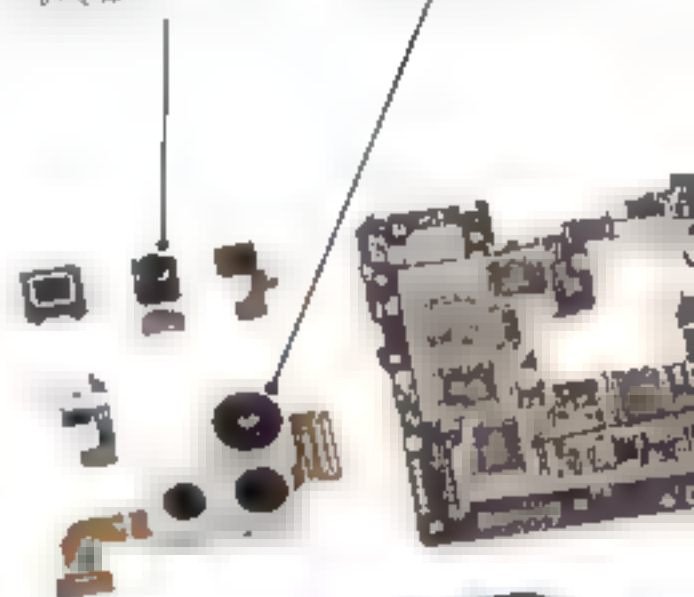
The 7.2-inch 1080p OLED screen is the largest in the industry, with a 20:9 aspect ratio. It's the first 5G phone to feature a 7.2-inch screen.

Front-facing camera

The 24MP front-facing camera is the first in the industry to feature a 24MP sensor. It's the first 5G phone to feature a 24MP front-facing camera.

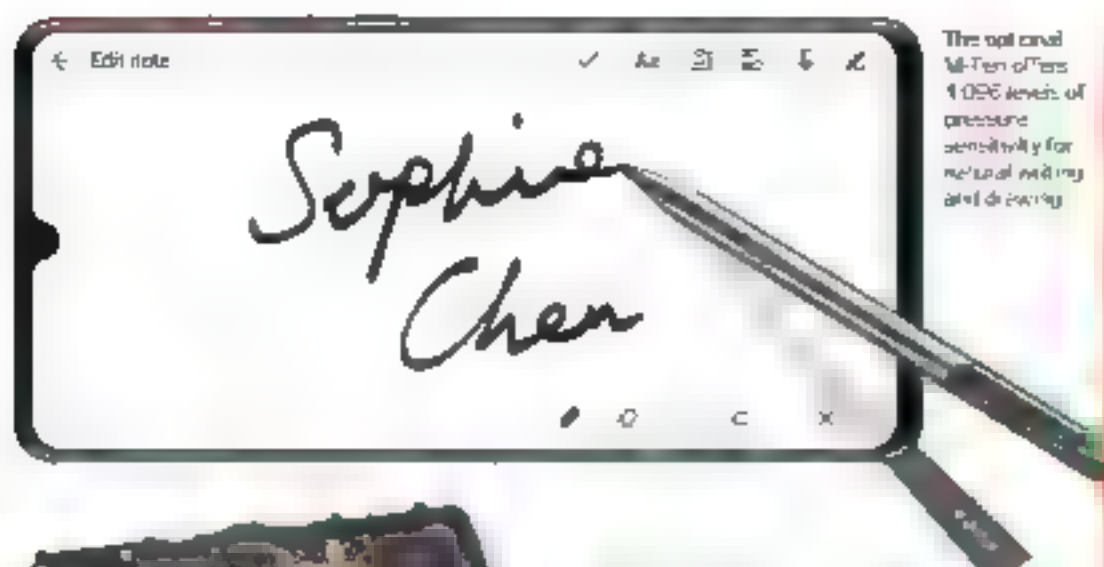
Camera housing

The camera housing is the first in the industry to feature a camera housing. It's the first 5G phone to feature a camera housing.



Speaker

The speaker is the first in the industry to feature a speaker. It's the first 5G phone to feature a speaker.



The optional M-Pen offers 4,096 levels of pressure sensitivity for natural writing and drawing

5G competition

Samsung Galaxy S10 5G

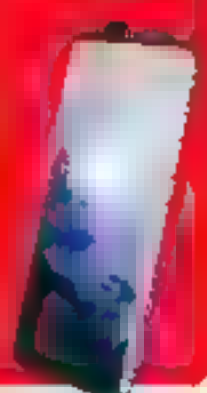
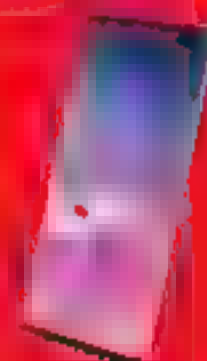
The big name Samsung's first foray into the 5G world comes in the form of the Galaxy S10 5G, which is expected to launch in early 2020. It's a sleek, high-end phone with a 6.7-inch display and a triple-camera setup.

LG V50 ThinQ 5G

Dual-screen option LG has a different take on 5G with the V50 ThinQ 5G. This concept phone features a second screen on the back that gives you extra space for multitasking. It's a bold move that could change the way we use our phones.

OnePlus 8 Pro 5G

Five photo pro This one's all about photography. The OnePlus 8 Pro 5G has a 108MP main camera and a 48MP telephoto lens. It's a phone for those who love taking high-quality photos and videos.



Motherboard

This is the heart of the phone, containing the processor, memory, and other essential components. It's a complex piece of technology that makes the phone work.

NFC and antenna

These components are used for wireless communication, including NFC payments and cellular data. They are small but crucial parts of the phone's internal hardware.

Rear casing

This is the back cover of the phone, which protects the internal components. It's usually made of a durable material like plastic or metal and is attached to the phone with adhesive.


Battery

The battery is the power source for the phone, allowing it to operate without being plugged in. It's a key component that determines how long the phone can last on a single charge.

SIM tray

This small tray holds the SIM card, which is used to connect the phone to a cellular network. It's a simple but important part of the phone's hardware.

"The phone is powered by the Balong 5000, Huawei's first seven-nanometre 5G chipset"



Road to a driverless future

Instead of you driving your car, soon your car could be driving you

Words by Alisa Harvey

They may not be working in progress, but driverless cars are leading us towards a future where taxi drivers are out of a job and no one holds the role of designated driver on a night out. Car companies like Lexus, BMW and Mercedes are developing this innovative technology in a race to release the first commercial self-driving car.

Up until recently, driverless cars were reserved for science fiction, but soon the roads could be covered in our Batmobile equivalents. Tesla estimates that its cars with "full self-driving" capabilities should be available before the end of next year.

They may still seem an entirely futuristic prospect, but the first research on these vehicles was conducted in around 1939. Admittedly a

much simpler concept, limited in possibility and not needing as many safety precautions.

Leonardo da Vinci designed a self-propelled cart. This cart is sometimes considered to be the world's first robot as it could move without being pushed or pulled. Steering was set in advance to determine its path – a method not too dissimilar to our future cars.

Much later, in 1943, the development of autopilot systems meant that aircraft used in

"Companies like Lexus, BMW and Mercedes are developing this innovative technology"



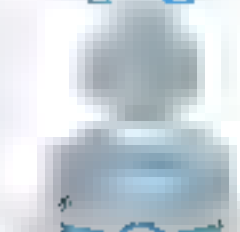
Yamaha is testing over 600 of its driverless cars in Europe, backed with



Driving automation levels

From hands-on to hands-free, these different levels measure how much the car takes control

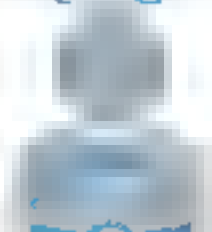
Level 0



Fully manual

are the most common cars that are currently on the roads. They require a driver to be fully alert and in control.

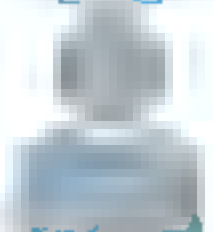
Level 1



Driver assistance

In systems that are about to be automated. Examples include lane-keeping and adaptive cruise control.

Level 2



Steering and speed

control. This means a driver can take their hands off the wheel for short periods of time, but they must still be able to take control at any time.

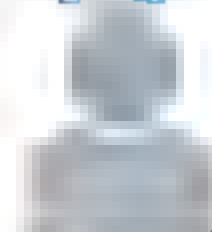
Level 3



Environment detection

The car can detect and respond to its environment, but the driver must still be able to take control at any time.

Level 4



High automation

The car can take control of the vehicle in most situations, but the driver must still be able to take control at any time.

Level 5



Full automation

Humans are not needed for driving. The car can take control of the vehicle in all situations, and the driver does not need to be able to take control at any time.

Crucial components

Each part of the car plays a vital role in steering and safety tasks that are usually carried out by humans

Video cameras

Visual information is used to detect and identify objects in the environment and to track their movement

Central computer

It processes data from all sensors and makes decisions about the car's movement

Lidar (light detection and ranging)

It uses a laser to scan the area around the car, measuring the distance to objects and creating a 3D map of the environment

GPS (global positioning system)

This system allows the car to know its location and direction

Accident-prevention systems

These systems detect potential collisions and alert the driver or take action to avoid them

Ultrasonic sensors

These sensors use sound waves to detect objects in the environment and measure their distance

Radar sensors

Radar sensors use radio waves to detect objects in the environment and measure their distance and speed

How a driverless car sees

Not only can cars now see, but manufacturers claim they can see better than us



Camera

Detecting lane lines and reading road signs, cameras can also see what the sun or headlights light up



Radar

Radar sensors use radio waves to detect objects in the environment and measure their distance and speed



Lidar

Scanning out millions of data points, lidar can detect even the smallest objects in the environment



lung. Hughes were able to fly without pilots continuously having to control the plane. Sperry Gyroscopic Co. was the company that designed the first autopilot prototype, and gyroscopes still play a huge part in driverless vehicle technology.

An important first step in developing the safety of driverless cars came in 1987, when German engineer Ernst Dickmanns installed cameras and 60 micro-processing modules onto a saloon to enable it to detect other objects on roads. Using them at the front and back of the vehicle, his system was programmed to only focus on relevant objects. Driverless cars use this to ensure that when on the road, they can spot hazards and prevent crashes.

However, when a pedestrian was killed by a driverless Uber car in 2018, questions were raised into whether this new technology will ever be safe enough. While they hold the potential to prevent accidents caused by human

"Gyroscopes still play a huge part in driverless vehicle technology"

error in both manual and autonomous cars are using the road at the same time, there's a higher chance of one acting in a way the other doesn't expect, increasing the chances of collisions.

Currently, the closest humans have got to testing the transport of tomorrow is using autopilot - a feature that Tesla introduced to its vehicles in 2015. Somewhere between manual and driverless, this hands-free tool for motorway travel was provided as a single software update for drivers. Overnight, customers were able to experience just a taste of the freedom that driverless cars will provide.



The driverless future is near

39.5%

The global increase in the driverless car industry each year

33 million

The number of driverless cars expected to be sold annually by 2040

50+

Google owns a large number of self-driving cars currently on the road

90%

Fewer traffic fatalities are estimated to occur in the driverless future

40+

Car and car parts manufacturers have announced they are working towards self-driving cars

10 seconds

The time it takes for a driver to take back full control of some current self-driving vehicles

257 kph

The speed reached by a self-driving sports car in testing

The most common accident involving self-driving cars is being hit from behind

A driverless car's AI could decide to risk its passengers' safety to save others outside

Inside a South Pole explorer



For the first time, a U.S. Navy expedition has used a specially designed crawler vehicle to travel across the ice to the South Pole. The vehicle, a modified Caterpillar 350C crawler tractor, is the largest and heaviest vehicle ever to travel across the ice to the South Pole. It is the only vehicle capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice. The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice. The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice.

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Power source

The vehicle is powered by a Caterpillar 350C crawler tractor, which is the only vehicle capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice.



Inverters

The vehicle is powered by a Caterpillar 350C crawler tractor, which is the only vehicle capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice.

Motors

The vehicle is powered by a Caterpillar 350C crawler tractor, which is the only vehicle capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice.

Weighty

The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice. The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice. The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice.

Caterpillar tracks

The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice. The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice. The vehicle is the only one capable of carrying a payload of 10,000 pounds (4,500 kilograms) over ice.



Special offer for readers in **North America**

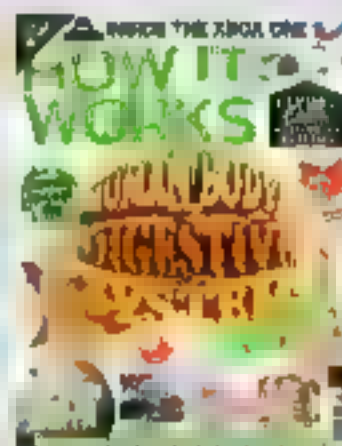


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Why Animals live together



Pollination is the perfect example of mutualism between two organisms



orking in the muddy waters of the river Nile, a crocodile carefully balances its eyes and snout above the surface. On the riverbank, a plover bird pecks at the ground.

Eyes trained on the feathered body, the crocodile paddles towards the unsuspecting plover before leaving the water and mounting the bank. With the crocodile's mouth now fully open, revealing the razor teeth within, the plover rushes over as if to greet the giant reptile. Rather than fear for its life, it begins to peck at the gaps between the crocodile's teeth, collecting ticks and debris as it goes. Undisturbed by this feathered flaking, the crocodile patiently waits for the plover to finish.

Each benefiting from the removal of parasitic pests, this reptile-bird interaction is a classic example of a symbiotic relationship. On a scratchy back and I'll scratch yours. Usable, many symbiotic relationships in nature can be beneficial for both animals concerned. However, not every partnership is equal.

The principle of symbiosis was first outlined to describe lichen, a plant-like organism that consists of both a fungus and algae. It was then later applied to different animals that lived in

mutually beneficial relationships and has since expanded to include three different types of relationship: mutualism, commensalism and parasitism. Each category describes varying levels of beneficial behaviour and interaction.

When two organisms both benefit from a relationship, it is known as mutualism. Benefits of having a buddy in the animal kingdom typically centre around food, protection and transport. Where one animal, such as the Egyptian plover, benefits at the expense of other benefits from the removal of parasites.

Examples of symbiosis in this form abound in the animal kingdom. For example, in the shallow waters of the Pacific, a crustacean and sea

"Many symbiotic relationships in nature can be beneficial for both animals"





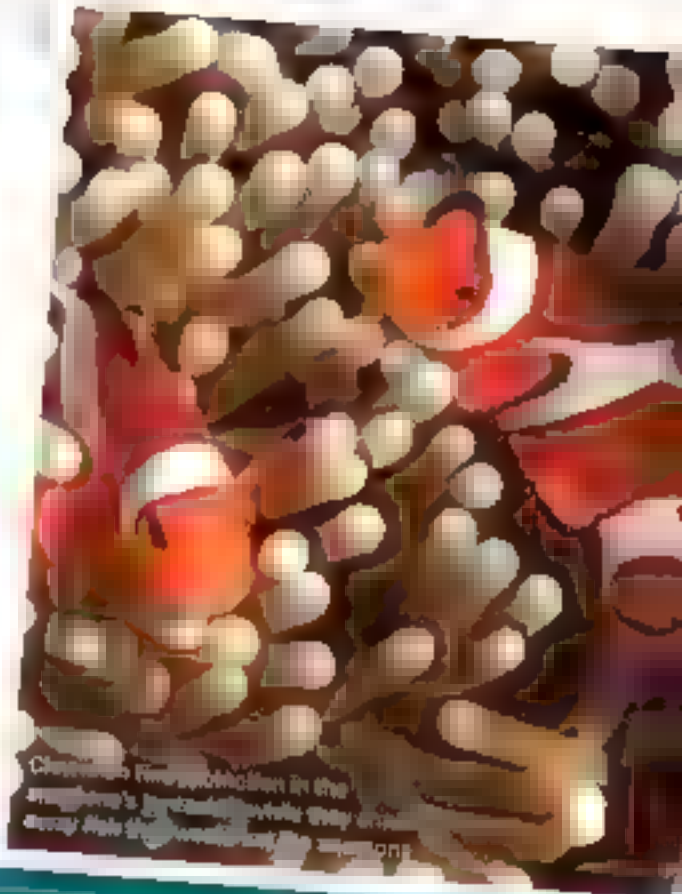
anemones come together to form the sea's only cheerleading crab. Often called the pom-pom crab or boxer crab, this high-spirited center swipes two anemones from the seabed and holds them in its claws. Known for their stinging ability, they offer the crab protection and a new way to catch food, while the anemones get a free place to land on organisms. The same principle applies to many different forms of marine life, such as the relationship between clownfish and anemones.

Above the ocean waves, examples of mutualism can be found across the world, from the oxpecker bird sucking the ticks dwelling on zebra ears to the hunting partnership of coyotes and badgers—however, one of the most abundant forms of mutualism comes in a global partnership between plants and animals: pollination. Here, a species of bird, mammal, or insect feeds on the nectar of plants, while brushing up against the plant's pollen or seeds,

which are then dispersed by the animal when it moves on. By visiting many flowers, bees introduce pollen and fertilize plants on their nectar-gathering journey, while deer might disperse seeds in their dung after feasting on nutritional fruit.

There are, however, relationships in which only one animal benefits from interacting with another, known as commensalism. It's a one-sided deal, but the species will take advantage of another without causing them any harm. On the underbelly of a whale shark, there are often several tiny fish hitchhiking a ride. These marine hitchhikers are called remoras, and

"Species will take advantage of another without causing them any harm"



Clownfish find protection in the anemone's tentacles while they eat away from the stinging sea anemone.

Microscopic mutualism

Sometimes two species can work so well together that they form a whole new organism.

Algae

Algae are tiny plants that live in water. They are found in all parts of the world, from the deep ocean to the surface. They are important for many reasons, including providing food for many animals.

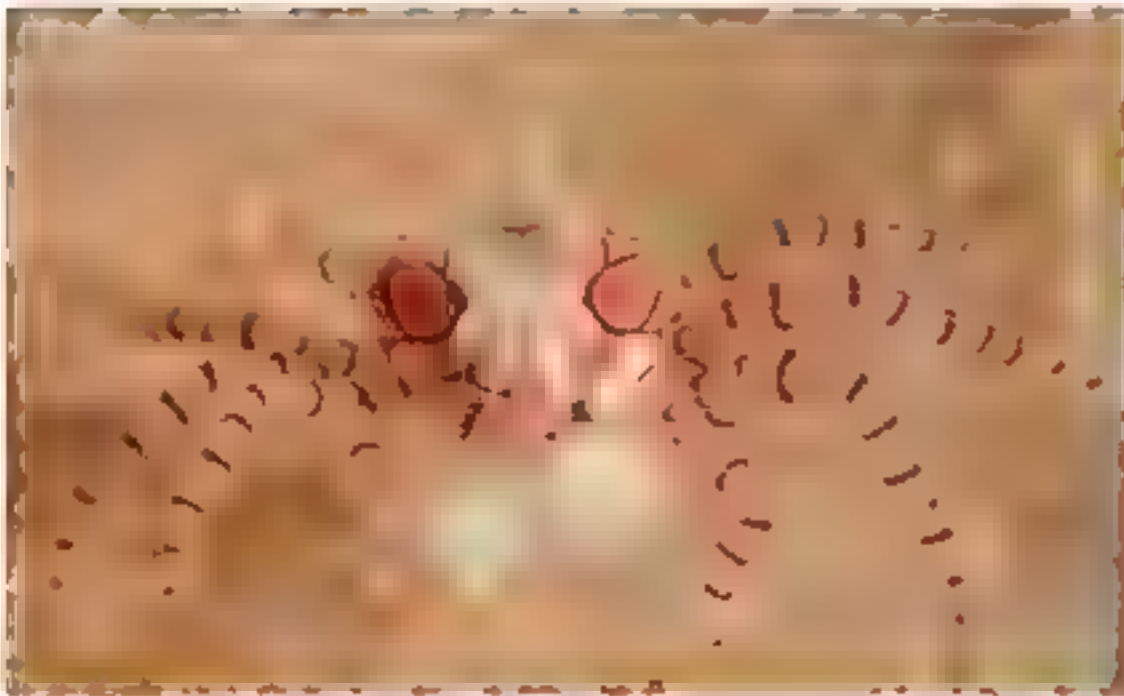
Reproduction

Algae reproduce asexually by dividing into two cells. They can also reproduce sexually, which involves the fusion of male and female gametes.

Fungi

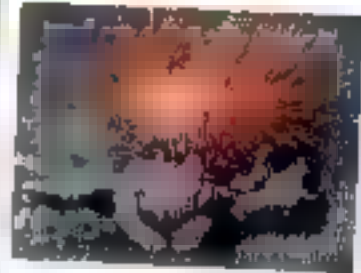
Fungi are organisms that can break down organic matter. They are found in all parts of the world, from the soil to the air. They are important for many reasons, including decomposing dead matter and providing food for many animals.

There are at least 1,000 different species of known symbiotic bacteria living in your gut



Crab & urchin

Often called the carrier crab, these crustaceans have been observed crawling along the sea floor with a spiky sea urchin on their back. The crab gains an armored shield against predators, and the urchin gets a ride to new feeding grounds.



Mongoose & warthog

Spotted in the ears of warthogs, mongooses find pleasure picking away at the many parasites living within a warthog's fur. The species gets a tasty meal, while the other gets a deep clean.



Tarantula & frog

A group of frogs, called microhylid frogs, share their tiny homes with a group of tarantulas. It is thought that these eight-legged bodyguards offer the frog protection, and the amphibians provides them with parasite removal services.



Zebra & ostrich

With poor eyesight but great hearing and smell, zebras seem to have partnered up with ostriches as a sensory replacement to detect predators. With excellent vision but poor hearing and smell, ostriches also benefit from their striped neighbors.



Goby fish & shrimp

Residing on the sea floor, goby fish and pistol shrimp work together to create themselves a perfect home. After the shrimp builds a burrow in the sea floor, the goby acts as a bodyguard against predators.



"These spineless worms grow within the bowels of their host, feasting on the digesting food"

Thanks to a specially modified dorsal fin they can suck on larger fish for easy travel. Equipped with many tiny, fleshy suckers, this suction cup fin creates enough friction to adhere to a scaly surface. By slightly changing the fin's shape, a remora can quickly detach. Without any benefit to the shark, remoras not only conserve energy, but after a shark has torn apart its prey, they can scavenge the floating debris.

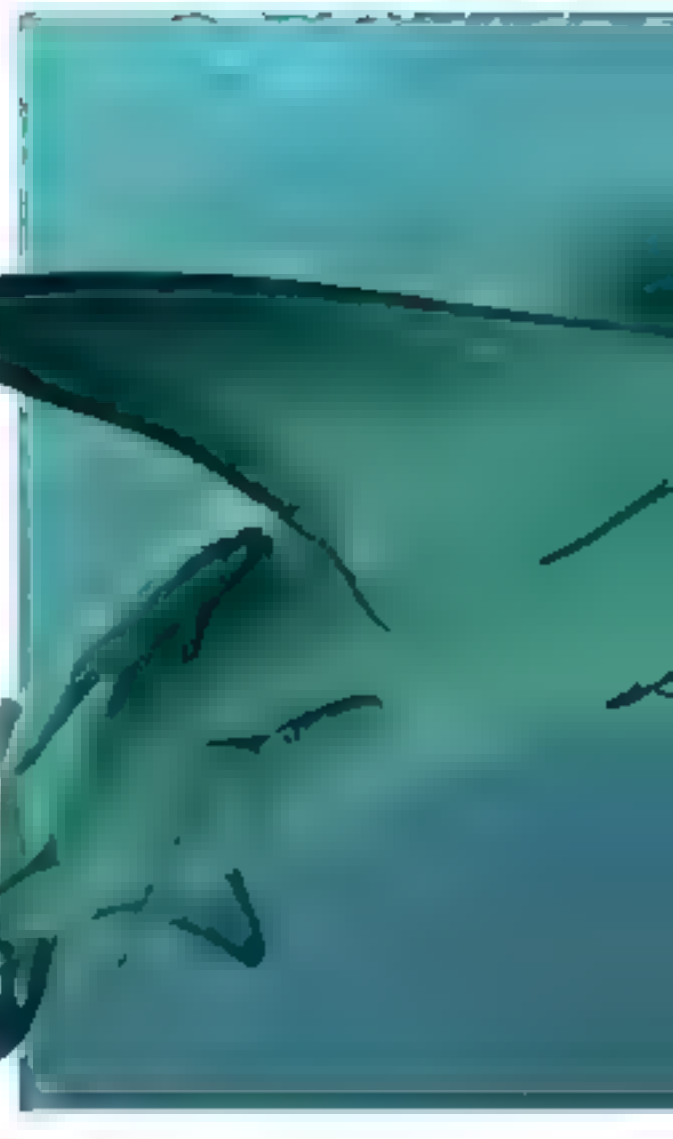
Woods jacks that have been expelled from their pack have also been witnessed to follow another species' movements to benefit themselves. Not on the heels of a tiger, these jacks will stalk jack cats in the hope of feasting on the carcasses of their latest prey. Undisturbed by the shadowing jacks, the tiger neither benefits from nor is hindered by its prey, whereas the jacks might get a quick and easy meal from the tiger.

In parasitism, however, one organism in this symbiotic relationship benefits at the expense of the other. The thought of the word parasite reminds one who sits at the table as a thief – an appropriate description as many parasites are blood-suckers or nutrient vampires. Often

starving just enough to feed themselves, parasites least without completely killing their hosts. Ticks and fleas, for example, live on their host's skin or nestled between their hairs, drinking the warm blood of their host mammal. Although just a few drops are more than enough to keep these tiny organisms alive, they pose an infection risk from the bacteria that they can transmit.

Some parasites work from the inside out, such as tapeworms. Once ingested as larvae, these spineless worms grow within the bowels of their host, feasting on the digesting food and even the surrounding tissue.

However, to ensure their position as a parasite, there are those that have evolved to become a physical part of their host. Hiding in the jaws of its fishy victims, the tongue-eating louse, a small marine amphipod, slowly replaces the tongue of its host fish, where it remains indefinitely. This parasite takes exploitation to a horrifying new level – in 2014, it gave one Finnish man a fright when he discovered a set of eyes staring at him from inside the mouth of a sea bass he'd freshly purchased from his local supermarket.



Crustacean got your tongue?

Discover how this tongue-eating louse replaces its host's tongue

Tongue-tied

Remoras attach to the tongue-eating louse and ingest the blood and tissue of the fish.

Through the gills

The remora's gills are located in the gill slits of the fish.

Tight grip

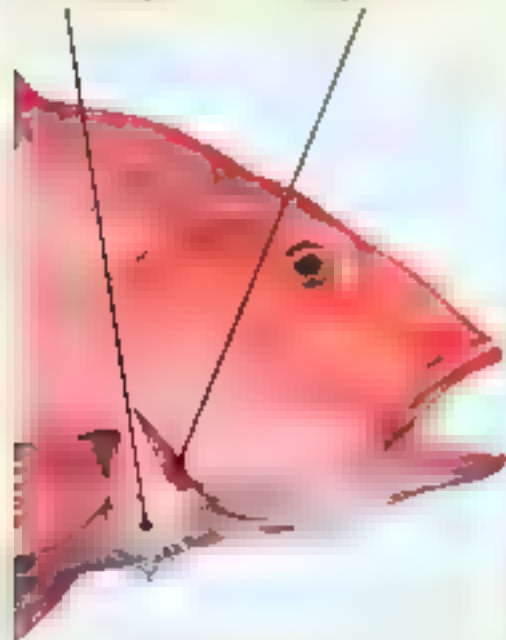
The remora's suckers are located in the gill slits of the fish.

Tasting the tongue

The remora's mouth is located in the gill slits of the fish.

Lifelong friend

The remora's mouth is located in the gill slits of the fish.



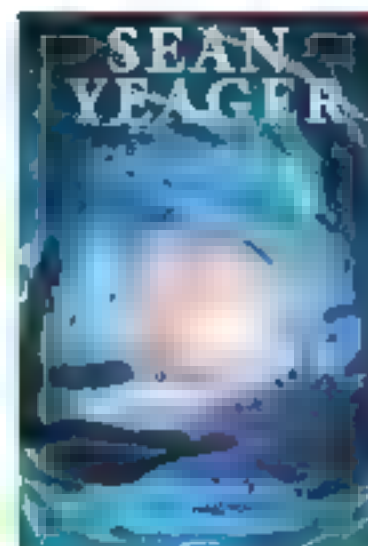
Mistletoe is a parasitic plant that can suck the life out of its host tree



Spore lets us look to the
way of larger fish for a free
ride through the world



**KEEP CALM
AND
AVOID ALIEN
PARASITES**



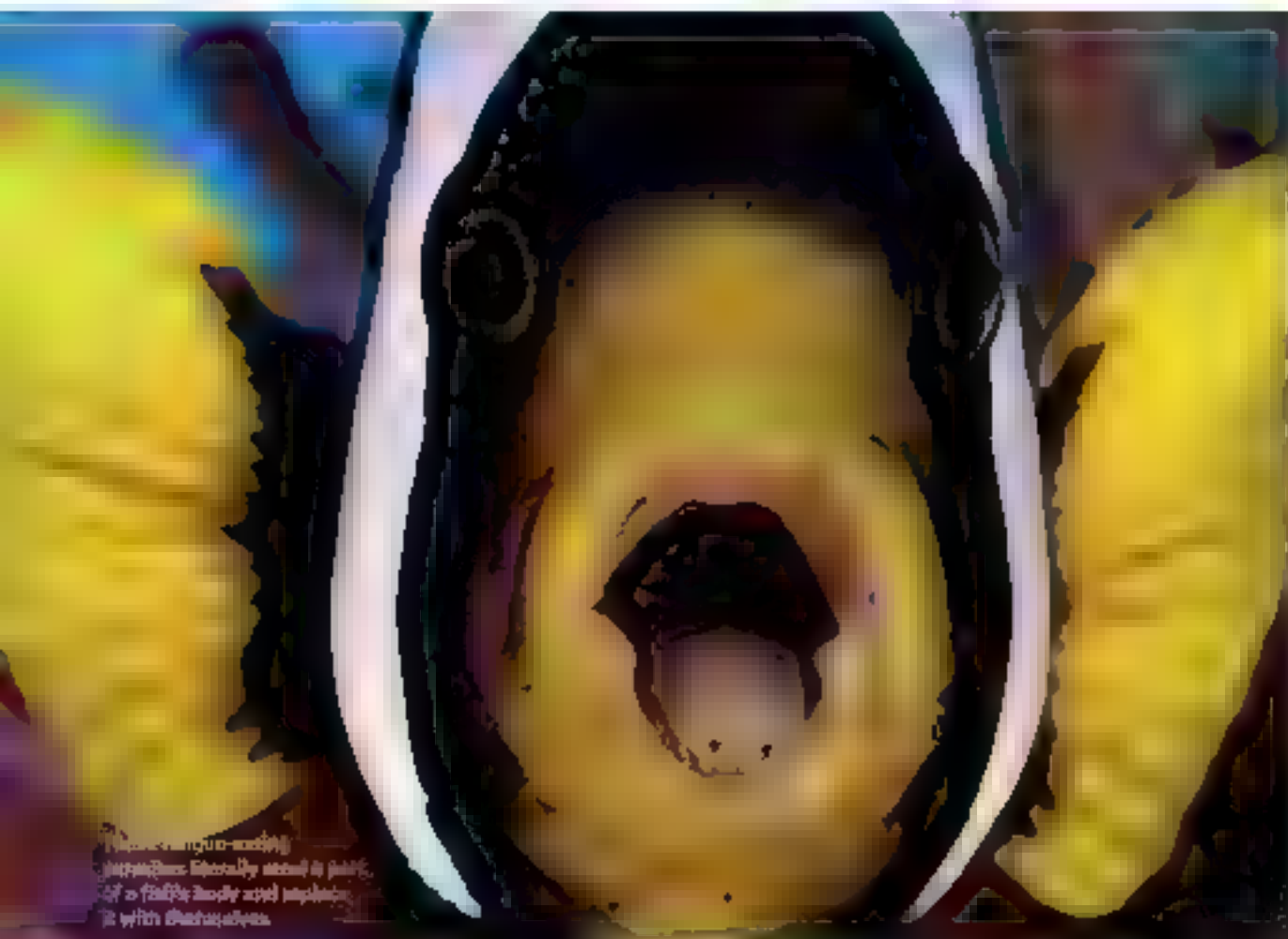
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Volcanoes: Making mountains from magma

Earth's volcanoes connect the planet's surface to its fiery core

Volcanoes are mountains and gateways to Earth's crust. These openings allow magma, volcanic ash and gas to escape during volcanic eruptions.

When a volcano erupts it can result in a huge, fiery explosion, throwing scalding lava into the air, or a gentle stream of lava running down the volcano's surface.

Often volcanoes are found where tectonic plates meet. These rocks make up the Earth's crust and are continuously moving, causing plates to rub against each other. The friction created by the movement of these plates creates a high temperature that turns the crust into molten hot rock, called magma. Regions with volcanoes formed during the movement of tectonic plates are called hotspots.

High pressures in the Earth's crust pushes magma up cracks in the tectonic plates until it emerges above ground level. When magma

reaches the surface it is called lava. As lava cools and hardens into volcanic rock, it forms a solid mountain of lava. Every time a volcano erupts, pouring molten lava out, it adds a little bit of lava to the volcano.

Not all volcanoes form in the same way. The viscosity of the lava that is released determines how steep or gentle the volcano's slope will be. This is dependent on how quickly lava cools to form the rock.

Volcanoes can also be found underwater in the form of submarine volcanoes. Because the lava instantly comes into contact with cool water, underwater eruptions often go unnoticed, if the top of these volcanoes come close to the water's surface. It is possible to see steam and debris being thrown above the sea. There are estimated to be over a million submarine volcanoes. Larger ones have the potential to grow above the water and become islands.

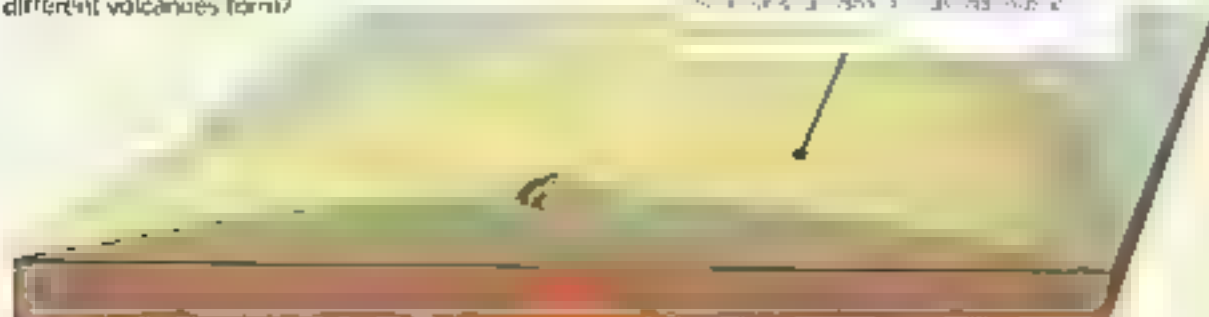


Volcano variations

From mega-mountains to hollow lakes: how do different volcanoes form?

Shield volcano

Shield volcanoes have the broadest, least explosive eruptions. They are formed by low viscosity, fluid lava flows.

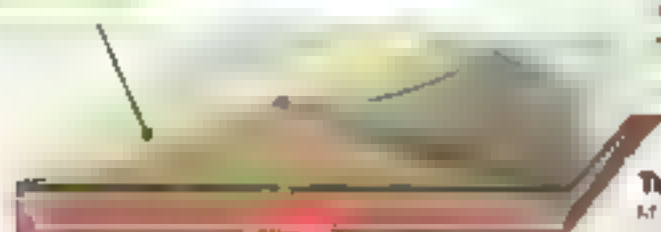


Complex volcano

Complex volcanoes have multiple vents and a central vent. They are formed by high viscosity, fluid lava flows.

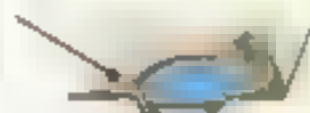
Stratovolcano

Stratovolcanoes are steep-sided, conical mountains. They are formed by high viscosity, fluid lava flows.



Maar

Maars are shallow, bowl-shaped craters. They are formed by the explosion of magma against groundwater.



Caldera

Calderas are large, bowl-shaped craters. They are formed by the collapse of a volcano's summit.



Tuff cone

Tuff cones are conical mounds of volcanic ash and tephra. They are formed by the accumulation of material around a vent.



Tuff ring

Tuff rings are ring-shaped mounds of volcanic ash and tephra. They are formed by the accumulation of material around a vent.



Pyroclastic cone

Pyroclastic cones are conical mounds of volcanic ash and tephra. They are formed by the accumulation of material around a vent.



Somma volcano

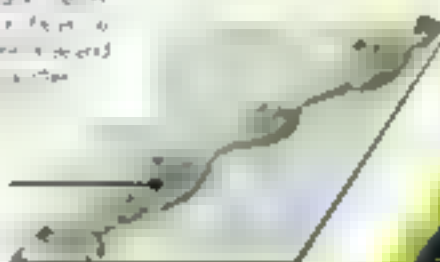
Somma volcanoes are a type of stratovolcano. They are formed by the accumulation of material around a vent.

Lava dome

Lava domes are conical mounds of viscous lava. They are formed by the accumulation of material around a vent.

Crater row, fissure vent

Crater rows and fissure vents are linear features. They are formed by the accumulation of material around a vent.



It's been a long time since we've seen a volcano erupt. The last time was in 1991, when Mount Pinatubo erupted in the Philippines.



How clouds reveal the weather

Clouds are the most visible part of the weather system. They can tell us about the temperature, humidity, and wind direction. They can also tell us about the amount of water vapor in the air.

Clouds are formed when air is cooled and the water vapor in it condenses into tiny droplets. These droplets then grow into larger droplets, which eventually fall to the ground as rain or snow. The type of cloud that forms depends on the temperature and humidity of the air.

There are many different types of clouds, each with its own characteristics. Some clouds are low and puffy, while others are high and wispy. Some clouds are dark and stormy, while others are light and fluffy. The type of cloud that forms depends on the temperature and humidity of the air.

Clouds are an important part of the weather system. They can tell us about the temperature, humidity, and wind direction. They can also tell us about the amount of water vapor in the air.

How do clouds form?

A journey to the clouds: how air carries water into the sky



Clouds that are everywhere

Clouds are a natural part of the sky, and they come in many shapes and sizes. Some clouds are thin and wispy, while others are thick and puffy. The clouds you see in the sky are made of tiny water droplets or ice crystals that have condensed together. Clouds can be found at different heights in the atmosphere, and they can last for a few minutes or for several days. The clouds you see in the sky are a beautiful and important part of our environment.



Cirrostratus

Cirrostratus clouds are thin, wispy clouds that cover the sky. They are made of ice crystals and can last for several days.

Cirrus

Cirrus clouds are thin, wispy clouds that cover the sky. They are made of ice crystals and can last for several days.

Cirrocumulus

Cirrocumulus clouds are thin, wispy clouds that cover the sky. They are made of ice crystals and can last for several days.

Reading the clouds

There are many different types of clouds, and they can be used to predict the weather. By looking at the clouds in the sky, you can tell if it will rain, snow, or be a clear day.

Cumulonimbus

Cumulonimbus clouds are large, puffy clouds that can grow very tall. They are made of water droplets and can last for several days.

Altostratus

Altostratus clouds are thin, wispy clouds that cover the sky. They are made of ice crystals and can last for several days.

Alto cumulus

Alto cumulus clouds are large, puffy clouds that can grow very tall. They are made of water droplets and can last for several days.

Cumulus

Cumulus clouds are large, puffy clouds that can grow very tall. They are made of water droplets and can last for several days.

Stratocumulus

Stratocumulus clouds are large, puffy clouds that can grow very tall. They are made of water droplets and can last for several days.

Nimbostratus

Nimbostratus clouds are large, puffy clouds that can grow very tall. They are made of water droplets and can last for several days.

HOW TO MAP THE MILKY WAY

Galaxies are the building blocks of the universe, and the Milky Way is no exception. It is a vast, spiral-shaped galaxy that contains billions of stars, planets, and other celestial objects. But how do we map this immense structure? The answer lies in a combination of advanced technology and careful observation. Astronomers use a variety of methods to map the Milky Way, including radio telescopes, infrared telescopes, and space-based observatories. These tools allow them to see through the dust and gas that fills the galaxy and to measure the distances between stars and other objects. By combining these measurements, astronomers can create a detailed map of the Milky Way, showing its spiral arms, central bulge, and the distribution of stars and gas throughout the galaxy.

One of the most important tools for mapping the Milky Way is the Gaia mission, a space-based observatory launched by the European Space Agency (ESA) in 2013. Gaia is designed to map the positions and motions of over a billion stars in the Milky Way. It does this by measuring the parallax of stars, which is the apparent shift in their position as Earth orbits the Sun. By measuring the parallax of a large number of stars, Gaia can determine their distances from Earth and their positions in the sky. This information is then used to create a 3D map of the Milky Way, showing the distribution of stars and the structure of the galaxy's spiral arms. Gaia's mission is expected to last for 10 years, and its data will revolutionize our understanding of the Milky Way and the universe as a whole.



position in the sky, but its distance away from us as well. In principle this can be determined by measuring the star's parallax – the angular change in its position as the telescope moves around the Sun. The problem is, the angle involved is minuscule, and gets smaller the further away the star is. Until the first astrometric satellite, Hipparcos – also operated by ESA – was launched in 1989, only about 8,000 stars had parallaxes large enough to be detected by ground-based telescopes. Hipparcos multiplied that figure by 15, increasing it to almost 120,000 – but that was only the first step. Gaia is going to measure the parallax of billion stars – 8,000 times as many as Hipparcos. This huge figure represents a sample of around one per cent of all the stars in the galaxy. Equally important, the sample will be evenly distributed across the whole galaxy, rather than being limited to nearby stars, as

Inside Gaia

From the outside Gaia may look like other space telescopes, but inside its design is unique

Thermal tent

For the cameras to work properly, the instruments must be kept at a constant temperature

The main solar panels are made of silicon and are covered with a thin layer of gold to protect them from the Sun's radiation

Main solar panels

These panels are made of silicon and are covered with a thin layer of gold to protect them from the Sun's radiation

Scientific payload

Part of the payload is the camera, which is made of two telescopes, each with a 1.8m diameter mirror, and a 1.8m diameter camera

Propulsion system

The propulsion system is made of 12 thrusters, each with a 1.8m diameter nozzle, and a 1.8m diameter camera

Service module

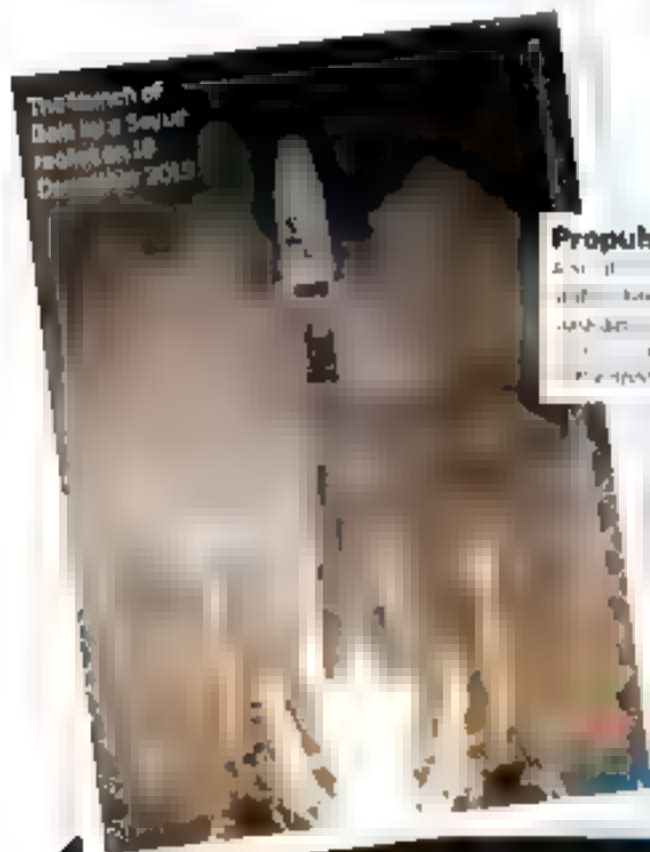
The service module is made of two parts, the main body and the service module, which is used to house the instruments and the camera

Downlink antenna

The downlink antenna is made of two parts, the main body and the service module, which is used to house the instruments and the camera

Additional solar panels

These panels are made of silicon and are covered with a thin layer of gold to protect them from the Sun's radiation



Unfolding sun shield

Gaia's optical instruments have to operate at a very low temperature, -130 degrees Celsius, in order to achieve the desired measurement accuracy. At the same time, the spacecraft needs to be heated in direct sunlight, so that its solar panels can provide enough energy to run all the equipment. To reconcile these two conflicting requirements, Gaia is fitted with a huge disc-shaped sun shield, more than ten metres in diameter. Made up of 12 hinged segments, the sun shield was neatly folded up around the spacecraft during launch, before opening out into its operational configuration once it was safely in space.



Shifting night sky

It's hard to map the stars when they're moving

Gala's most important job is to establish the distance to a star by measuring its parallax – the amount it appears to wobble in the sky over the course of a year. If stars always remained in fixed positions in the galaxy, the only movement during this time would be Gala's annual orbit around the Sun. So any apparent change in a star's position would have to be due to parallax and nothing else, and Gala's task would be easy.

In reality, stars – including our own Sun – don't stand still; they travel in huge orbits around the centre of the galaxy. Unlike planets in a solar system, these orbits aren't always neat circles or ellipses, but can be complex trajectories. The result, seen from Gala's perspective, is that each star has its own unique 'proper motion' – reflecting its real motion through space – on top of the parallax effect Gala is trying to pin down. This means that Gala has to make a whole series of measurements, spread over several years, in order to separate the star's steady drift (proper motion) from its year-to-year oscillatory motion (parallax).



Large star orbit



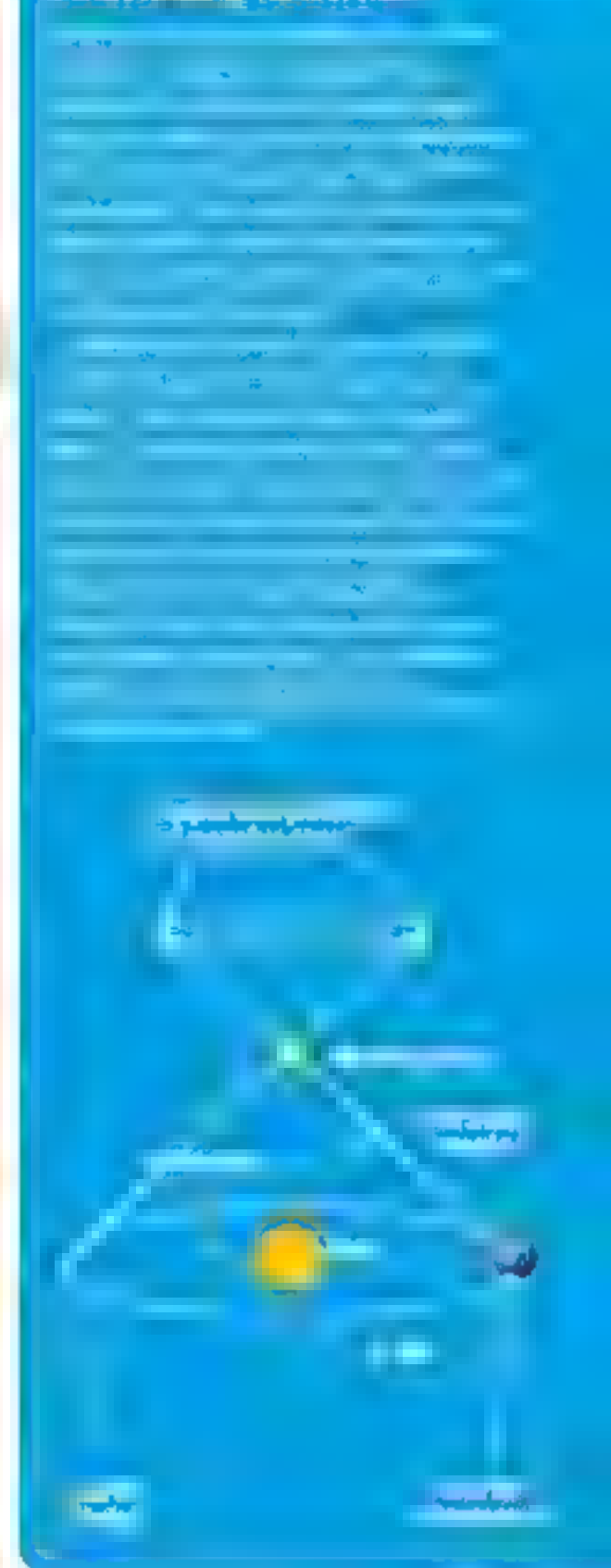
Small star orbit

Star orbit

An image of the Milky Way and beyond created from Gala's observations



Star parallax



This view of Gala prior to launch gives an idea of its huge size

Galactic structure

We can see the nearest pictures yet of the galaxy, from the spiral arms and central bulge to the outer halo.

History of the galaxy

Our knowledge of the timeline of star formation and the galaxy's changing chemical composition, as well as accurate ages for its oldest stars, can be improved.

Brown dwarfs

So far, they're almost invisible to direct from Earth. Gaia will revolutionise our knowledge of these tiny stars.

Physics of stars

Although a well-studied field, there will still be a lot to discover – for example, in the physics of white dwarfs and giant stars like Rigel.

What Gaia could discover

The observations made by Gaia will feed into virtually every branch of astronomy.

The scale of the universe

Position in the 1st star in the nearest distance table, with its spin rate indicated by superimposed arrows using Gaia's data.

Planets around other stars

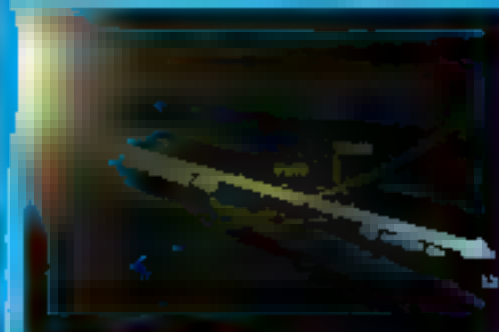
A huge topic thanks to NASA's Kepler telescope. Gaia's high-precision astrometric measurements will detect many more of these.

Fundamental physics

Probing the Einsteinian, Schwarzschild realm, slightly as it passes objects in the Solar System. Data can test, that.

A good spot for a space telescope

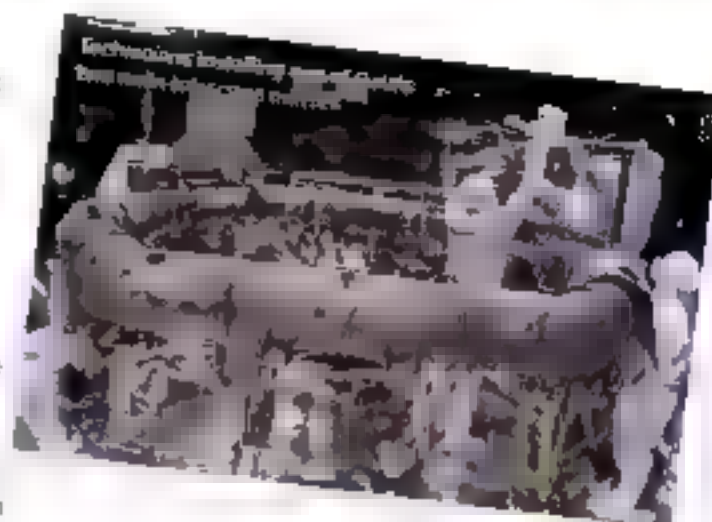
Galileo's mission is to map the Milky Way, the galaxy that contains our solar system. It's a massive task, but Galileo is well-equipped for the job. The spacecraft has a suite of instruments, including a camera, a spectrometer, and a Doppler shift meter. The camera will take images of stars and galaxies, while the spectrometer will analyze the light from these objects to determine their composition and temperature. The Doppler shift meter will measure the velocity of stars along the line of sight, which will help astronomers determine their distance from Earth.



was the case with Hipparcos and the earlier ground-based parallax measurements.

Galileo uses a trick pioneered by Hipparcos that makes it easier to measure incredibly tiny parallax angles. Rather than a single telescope, it has two identical telescopes pointing in different directions. By combining the two images and processing them together, this means that only relative – rather than absolute – positions of stars have to be measured, making the task a lot simpler. ESA aims to obtain parallaxes for every star that Galileo looks at – which is an impressive enough goal in itself. But on top of that, Galileo has other instruments that will be used on a subset of the stars observed – for example to measure Doppler shifts – which indicate a star's velocity along the line of sight – as well as various physical properties of stars, like temperature and chemical composition.

Observing 1 billion stars may sound challenging enough – but Galileo isn't just going to look at each of them once or twice – but around 100 times. That's necessary in order to obtain



sufficiently accurate measurements of parallax as well as the star's true motion through the galaxy. The result will be one of the biggest scientific databases ever created – over 100,000 gigabytes of raw data – increasing to perhaps ten times that amount after it's all been processed. The result – the first two statements of which have already been released into the public domain – will be the biggest and most complete census of the galaxy ever undertaken.

"The result will be one of the biggest scientific databases ever created – over 100,000 gigabytes of raw data"

Making sense of it

In the course of its mission, Galileo is expected to transmit hundreds of thousands of gigabytes of data back to Earth. A mechanically steered radio antenna would interfere with the precise astronomical measurements, so an electronic antenna with no moving parts is used instead. After it's picked up by ESA's network of ground stations, the raw data is passed to Galileo's Data Processing and Analysis Consortium (DPAC) – a team of 450 scientists spread across Europe and beyond. Their job – one of the biggest and most challenging in the history of data processing – is to make scientific sense of all that data. Once that's done, it's released into the public domain on a roughly annual cycle.



Space elevators

The idea of a lift to destinations beyond Earth's atmosphere has been dreamt of by scientists for over a century

Travelling into space, a prospect which once seemed an almost impossibility, could one day be as simple as stepping into an elevator. The concept has been studied for decades, proposing to transport cargo into space. Aiming to eventually carry humans, they would provide a permanent and cheaper alternative to rockets.

Imagine putting your hand on a button and reaching your level a few days later, or even in a week's time... space elevators will consist of a cable that needs to be robust enough to cover the 35,786 kilometres between the Earth's surface and the edge of geostationary orbit – the point where satellites follow Earth's rotation.

In the proposed design, a cable roughly 200 million times longer than its width attaches to an enormous orbiting counterweight. Gravity working on Earth pulls the cable

downwards towards its surface, while the opposing centrifugal force pulls the counterweight outwards.

The concept of a space elevator was first described by Konstantin Tsiolkovsky in 1895, albeit much simpler. Inspired by the Eiffel Tower, he put forward the idea of building a tower high enough to reach into space. The theory made sense, but in practice it was flawed, as the bottom of the tower would be unable to withstand the weight above it. Using tension, the new cable system is more mechanically viable.

Unlike traditional elevators, space elevators won't use moving cables to lift a platform. Instead they'll use 'climbers', with people or objects inside, travelling along a single stationary cable. Many of these climbers would need to be moving at the same time and in both directions to prevent the vibrations disrupting their motion.

While there have been many proposed plans for the construction of space elevators, studies show that they are implausible until a suitable material that can support the tension created in such a huge construction is found.

Engineering the elevator

Space elevators may appear on the Moon before Earth, as less gravity makes them easier to install

Making space travel less expensive

Last year, over 100 rockets were launched

but only a few of them are successful and the expenses required to reuse these rockets for space travel is huge. Sending just one kilogram into space using this method costs tens of thousands of dollars.

Not only is the building of rockets costly, powering them with a constant supply of fuel adds to the expense.

This is where space elevators show potential. Some predictions state that space elevators could make space travel 1,000 times less expensive than it is today. They would make the world beyond our planet more accessible with

could make launches more cost-effective



Ground station

located in the middle of the Atlantic Ocean, there are the highest and strongest winds

DID YOU KNOW? The anchor holding down the cable of a space elevator will be as heavy as 170 school buses



Tether

It is a 36,000 km long cable
 that is made of a special
 material that is very strong
 and can hold a lot of weight

Climber power source

It is a solar panel array
 that is attached to the climber
 and provides it with power

Climber

It is a small vehicle
 that can climb the cable
 and carry a payload of up to
 10,000 kg

Solar space elevator power

The solar panels on the climber
 will collect energy from the sun
 and send it back to Earth via
 a laser beam. This energy will
 be used to power the climber
 and the other equipment on the
 elevator.



"Space elevators could
 make space travel 1,000
 times less expensive"

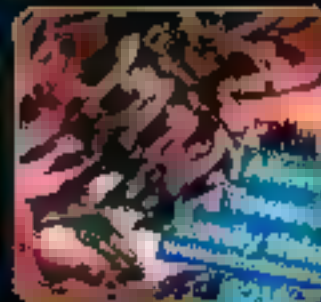
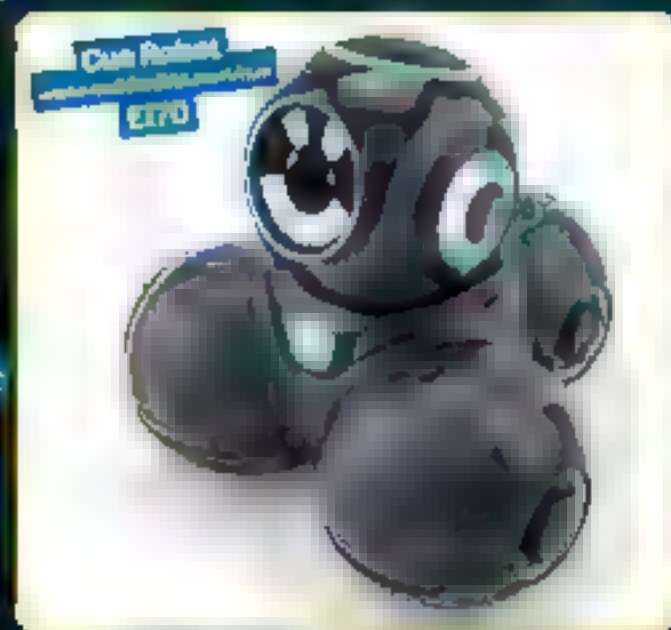
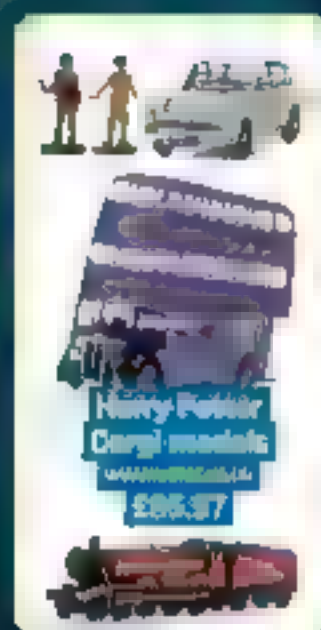
Articulated manned manipulator

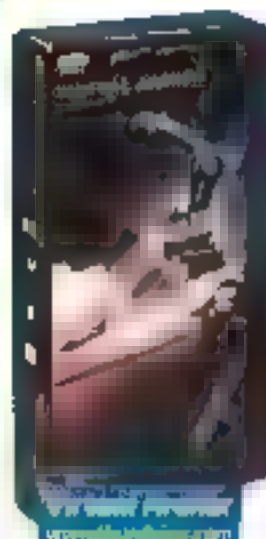
An example of a manned
 manipulator is the one used by
 Apollo 16 to move potential lunar
 rocks on the Moon.

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To celebrate ten years since *How It Works* first hit the newsstand, we are giving away an amazing bundle of gadgets, games, tech and toys.

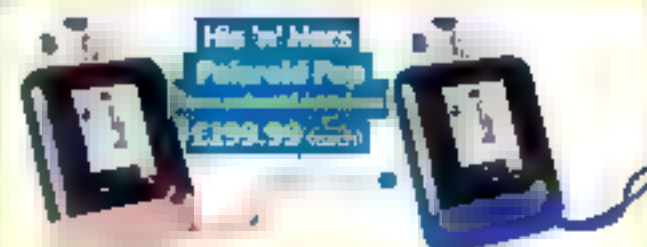




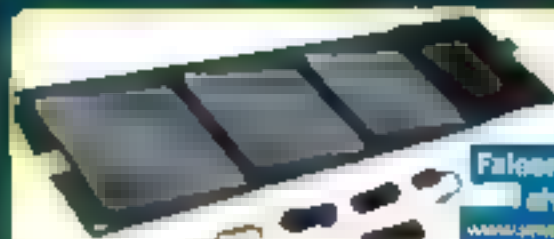
The Bill
www.bbc.com
£34.99



**Celestron
NexStar 4SE**
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£399



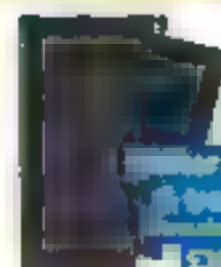
**His 'n' Hers
Polaroid Pop**
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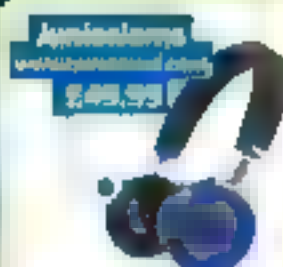
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WP-PRO**
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£279.99



Leather jacket
£100



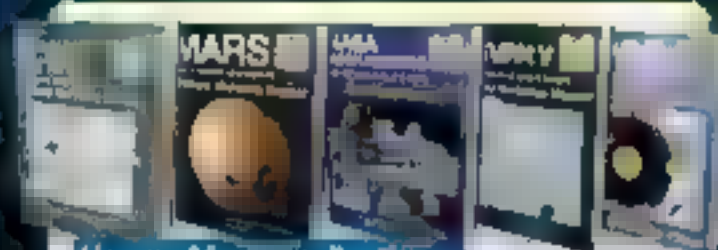
Headphones
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In what year did the Titanic sink?

a) 1792 b) 1850 c) 1912

Alternatively, you can write to us with your answer to this address:

How It Works, Future Publishing, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ

Terms and Conditions: Competition closes at 00:00 GMT on 27 November 2009. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules at www.howitworks.com. Entries must be received by 00:00 GMT on 27/11/2009. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

BRAIN DUMP

Because enquiring minds need to know

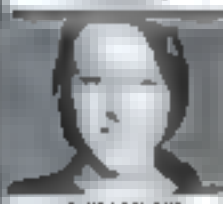
How long would it take to run a light year?

Low Point

A light year spans nearly 9.5 trillion miles. Let's assume that the runner is as quick as the world's fastest ever marathon runner, Eliud Kipchoge, who completed the Berlin Marathon in just over two hours in 2018. We'll also say that they'll never age, and they'll never tire. Even then it should take the runner over 36 billion years to run an entire light year. **26**

MEET THE EXPERTS

Dr. [Name] is a [Title]



Want answers?

Fastest world-record marathon runner would need 36,527,536 years to run a light year



Why do trains always run on tracks instead of roads?

Jonny Bombardier

■ Trains can go much faster than cars, because there's less friction between steel wheels and steel tracks. For cars, there is between rubber tyres and asphalt roads. JS



Do all animals have wisdom teeth?

Bailey McClellan

■ As other toothed mammals have, these teeth, but we have evolved not to need them due to our modern diet of mainly softer, cooked foods. Wisdom teeth, also known as third molars, grow towards the back of your mouth and are used for grinding up very tough foods, such as plants and raw meat. JS

www.boredom.com





Why can't I touch my toes?

Alexia Bartolomeu

■ The main factors in being able to touch your toes are the flexibility of your hamstrings (back of your thighs), the range of motion of your hips and the length of your arms and torso compared to your legs. Regular stretching can help you to touch your toes. **JT**



Can parasites get parasites?

Abdul Khan

■ Parasites that infect other parasites are called 'hyperparasites'. Take crypt-keeper wasps, for example. They parasitise gall wasps, which parasitise plants. Gall wasps trick trees into building safe chambers for their larvae. Interestingly, some grow the caterpillar.

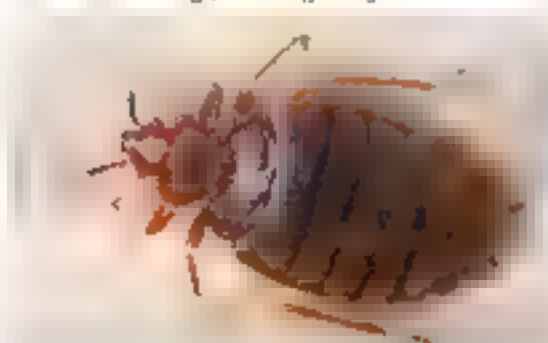
When the larvae mature, they usually bite their way out, but crypt-keeper wasps

intercept the process. They lay their eggs inside the galls, next to the gall wasp larvae. Under the influence of a crypt-keeper larva, a gall wasp larva can only chew a tiny hole in its gall before it gets stuck. This gives the crypt-keeper larva time to eat the gall wasp larva, chewing through from tail to head and out into the open. **LM**

How do you get bedbugs?

Dennis Pierre

■ Bedbugs are small insects that love to live inside furniture, such as sofas or beds, and can bite humans, leaving itchy marks on the skin. One way they can get into your house is by hitching a ride on you, your clothing or possessions if you've come into contact with an infested site (like a cinema seat or a hotel bed). Alternatively, they can hide inside any furniture or soft furnishing you bring into your home. **JS**



How fast is the world's fastest computer?

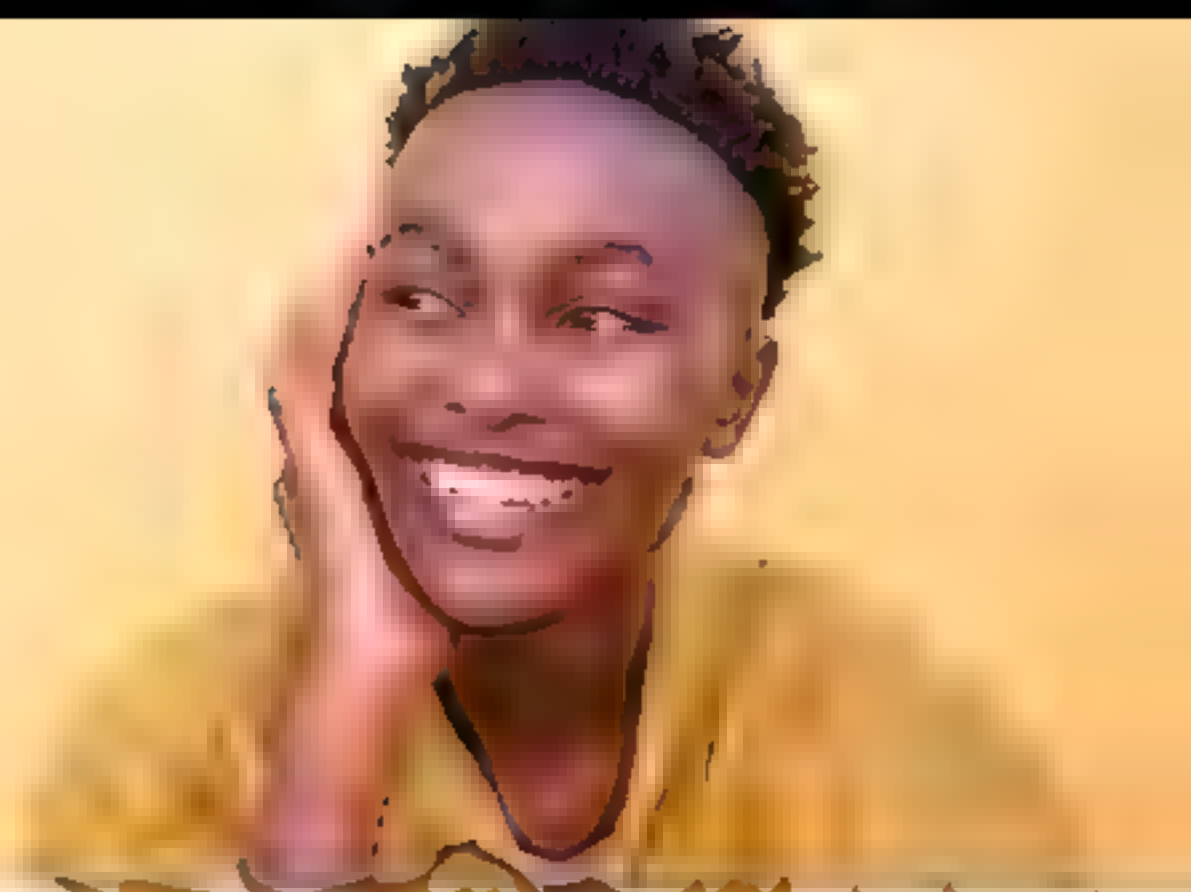
Xiaoteng Ji

■ Summit, a supercomputer at Oak Ridge National Laboratory in Tennessee, USA, can perform 100,000 trillion calculations per second. It has 4,600 computer servers and is the size of two tennis courts. **BE**

Can being happy help you to live longer?

Maurice Jasper

■ Experts still disagree about this, but a 2014 study by researchers at University College London found that feelings of satisfaction in older individuals was linked with an increased lifespan. So keep smiling. **AM**



What does the 'D' in D-Day stand for?

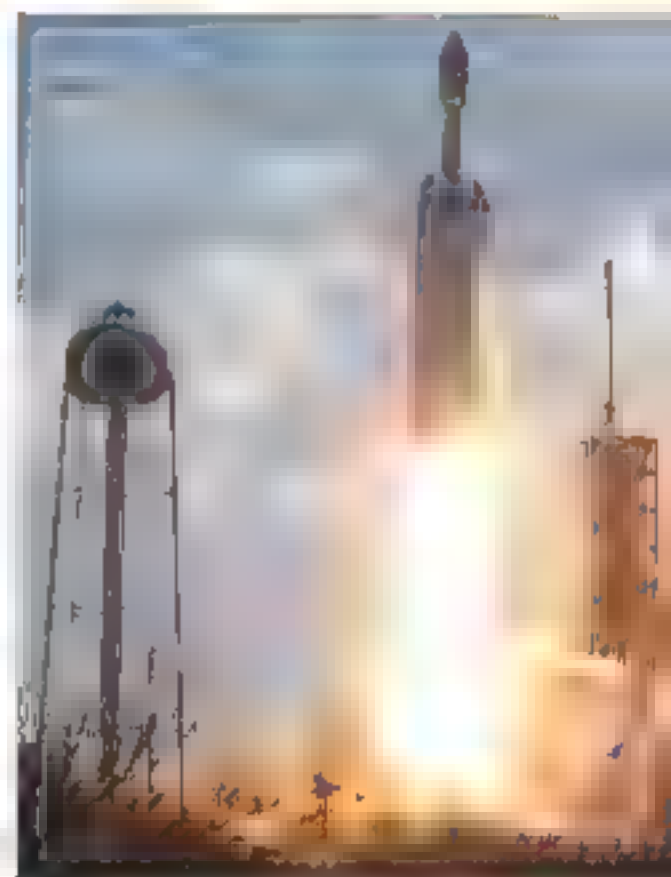
Clive Burchell

■ The 'D' in D-Day actually means 'day'. Although the invasion of occupied France which began on 6 June 1944, is the best-known operation to feature a D-Day, it was in fact a common term used during military planning

to denote the first day of an operation or invasion. Every subsequent day in the planning stage would therefore be labelled D + 2, 3 and so on. Military planning also commonly used H-Hour to specify an exact hour of the launching of an operation. **BT**



Troops from 480th Royal Marine Battalion Beach, Normandy, France during the D-Day landings

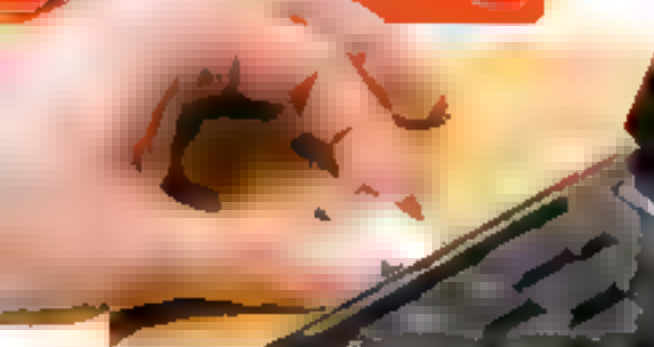


When will our next manned mission to the Moon or Mars be?

Ali Puddlechurch

■ NASA hopes to land people on the Moon again as early as 2024, but people visiting Mars for the first time is much more difficult. NASA suggests it could have a manned Mars mission in the 2030s, but SpaceX ambitiously predicts that it could get people to Mars by 2024. As with any ambitious new development, there is a lot of uncertainty because the financial and technical challenges are huge. **TL**

BRAIN DUMP



Do I have to eject my USB drives before shutting down?

Katie McClelland

It's recommended that you eject a USB drive before removal. To prove it any data copied files run the risk of being severed mid-transfer, which corrupts them. But a proper shutdown procedure will stop the transfer of any files, so it can be to remove a USB after the computer is switched off. **OK**

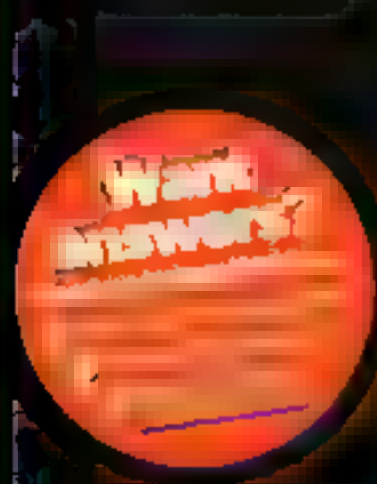
What is the Rosetta Stone?



Which organs can I live without?

Raj Hart

Q The human body is surprisingly robust and rather amazingly can still function even when missing a multitude of organs. Some of these organs are important but help to defend us against harmful microorganisms, such as our tonsils and appendix. And in some cases we have a spare, such as with kidneys and lungs. Overall, a person could continue to lead a fairly normal life without an appendix, tonsils, a lung, a kidney, the spleen, some lymph nodes, salivary glands, ear organs, a loop of bowel from the stomach (up to six) and the bladder in the male. **OK**



The human body is very robust and can continue to survive without several organs.

What is the biggest tablet device in the world?

Jobb Stones

■ If we're including April Fools jokes, the record would go to the 42-inch slablet by Ocado. The largest real-life tablets we could find are the 27-inch Lenovo Yoga Home 900 and the 28.4-inch Samsung Galaxy View. **JS**



Why are there so many castles in Britain?

Laura Torres

■ Britain was in a state of civil war for much of the Middle Ages, as nobles feuded with each other or revolted against the king. Lords and kings built castles for protection and to control

lands. Other castles were built by invaders to stamp their authority, such as the motte and bailey castles built after the Norman Conquest. At other times castles were built to defend against foreign invaders, like Henry VIII's

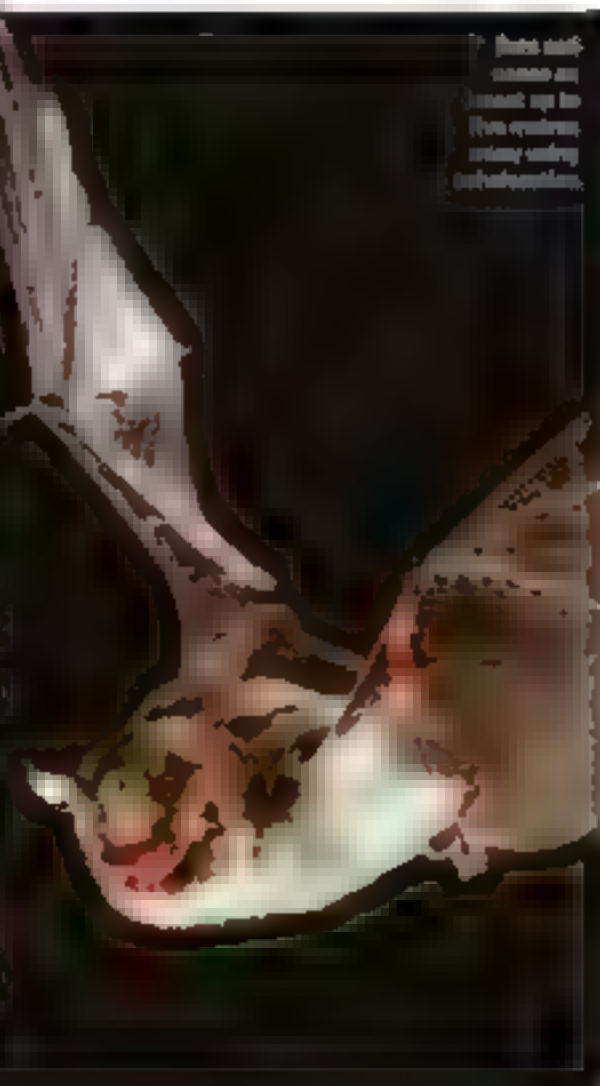
coastal forts, or later as homes. Castles were also built when England, Scotland and Wales fought wars with each other. As a result of this long and warlike history, over 1,500 castles were built in England alone. TL



What is echolocation, and which animals have it?

Nora Wigby

■ Animals in the air, underground and underwater can't rely on sight alone to detect the world around them. Instead they use a technique called echolocation—emitting ultra-high-frequency sounds from the mouth or nose and listening for the echoes when the sound waves bounce off nearby objects. The time it takes for the echo to reach them and the direction of travel tells the animal the size, shape and location of the thing around them. Bats, for example, can detect objects as thin as human hair in the darkness. Other animals that use echolocation include dolphins, shrews and some birds and insects. TL



Bats use sound waves to hunt up to five miles away using echolocation.

Where does the phrase 'cold feet' come from?

Samuel Thorn

■ People have been using the phrase 'cold feet' to mean having second thoughts for at least 100 years, but none is quite sure why. Some people think the phrase comes from soldiers complaining of numbness before battle, but I bet that they wouldn't have to fight if they paid in to a similar phrase—military jargon for the obvious, where a cold state of feet stands in for no money. TL

There are really dozens as to why we say 'cold feet' when someone has second thoughts.



BOOK REVIEWS

The latest releases for curious minds

Interplanetary Robots

True stories about unmanned space missions, past and future

■ Author: Rod Pyle ■ Publisher: Prometheus Books
■ Price: £14.99 / \$18 ■ Release: Out now

There are plenty of stories about Earth's manned space missions. From triumph to tragedy, the personal stories of those brave men and women have been told in every journal, TV show, interview, book and film. But while we are always keen to hear the stories of the people who have visited the stars, the same can't often be said for the machines that went during the same

However, in recent years, with funding to agencies like NASA cut back, manned missions have been held in check. And, likely buoyed by clever science-fiction novels, TV series and films, the interest in unmanned missions has risen. For anyone excited about Curiosity's ongoing Mars mission or intrigued by the prospect of the ARIEL rover launching Venus at some point in the future, this book will surely grab your attention.

For a glimpse into the annals of space missions of the past and future, *Interplanetary Robots* tells the stories of mankind's previous attempts (both successful and not) to chart the stars and explore the planets in our Solar System. In fascinating chapters, author (Rod) Pyle looks back at one of the pioneering spacecraft that helped us glimpse new parts of our Solar System, and future missions that may help us understand more about ourselves.

Pyle draws on his experience working at NASA's Jet Propulsion Laboratory (JPL) and includes regular anecdotes about his encounters on the ground. We also hear about the 'blatant case of Mars died' for an eight-year-old Pyle as *Mariner 4* beamed the first grainy photos of a barren desert back to Earth and watched the dreams of science-fiction writers everywhere. And

the moments before the Curiosity rover landed as he and other space journalists waited patiently together at NASA to see the results.

What the book does a great job of is highlighting how, despite being entirely robotic, these missions were *human* through and through. He tells these stories – and those of the missions themselves – in engaging prose. And as he looks to the future, he's sure to spark excitement in the growing number of us looking to the stars. It's unlikely all the missions he mentions will reach the launchpad, but as NASA and others set their sights on the Moon once more, this book is a nice way to prepare.

★★★★



Despite being entirely robotic, these missions had human stories at their core



Science The Sh*t Out Of Life

Anything Matt Damon can do...

■ Author: Colin Stuart, Mun Keat Lo
■ Publisher: Andre Deutsch
■ Price: £14.99 / \$18
■ Release: Out now

Mark Watney in *The Martian* survived being stranded on Mars by using a whole load of science, and while it's unlikely that any of us will ever have to do it, his practical scenarios here are still a number of ways that it can be applied to everyday life.

For the most part, the conundrums that Colin Stuart and Mun Keat Lo attempt to resolve are that bit more trivial: how to cure a hangover, how to be a better saver and the best way to get ketchup out of a bottle. Not all of them are especially helpful (we're looking at you, hangover solution – don't drink really doesn't count), but some might have you surprised.

Refreshingly, this isn't another heavy either. While some books of this ilk focus purely on the figure-crunching, this is more focused on keeping things fun and reliable, and appealing to the regular reader rather than the average scientist. You do want to know how to build the perfect paper aeroplane, right?

So in short, this is a handy manual for those who need help navigating some of the more trivial decisions in life, or who just want to see things from another direction. Either way, there's plenty of fun to be had.

★★★★

Believe It Or Snot

Who nose what to expect?

- Author: Nick Caruso, Dani Nabalotti
- Publisher: Quercus
- Price: £9.99 / \$16
- Release: 17 October (UK) / 22 October (US)

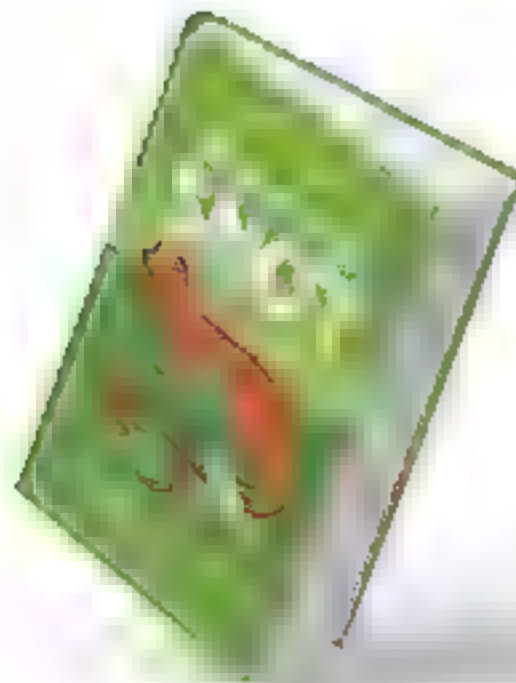
We were fans of *True Or Pon*—probably because of the title, to be honest—so it was always going to be likely that we would find something to enjoy here too, again, mainly because of the title. And we weren't disappointed.

Saying that, the title is a bit of a misnomer. It isn't, as focused on slimy creatures; everyday mammals like giraffes and dogs have their nostrils and their contents put under the microscope, and the chances are you'll like

what you find. Want to know how much slime a hogfish can produce in a minute? Reckon birds aren't especially smelly for lack of a better word? You could have your world rocked.

Inevitably, its appeal will be more for younger readers. Some sports fans tend to grow out of this subject matter. If you haven't, though, then this is something that might well be worth picking up.

★★★★★



Inventor Lab: Awesome Builds For Smart Makers

DK gets interactive

- Author: DK
- Publisher: DK Children
- Price: £12.99 (approx \$16)
- Release: Out now

We're great fans of DK and the way the publisher seamlessly blends excellent photography and illustrations with enlightening articles and captions. This book, however, comes with a difference: rather than reading about how things work, you get to make them work yourself.

Starting with the very basics, such as guides to circuit components—like capacitors, resistors and transistors—and how to use the required equipment, it then takes you through how to create various devices. These include electromagnetic cranes, door alarms and even a remote-controlled snake. There's no shortage of options here.

Even if you don't have the necessary equipment on hand to create some of the things in this book, there's still plenty to recommend. The instructions are clear and serve an educational purpose, as well as a refresher for those who have unlearned what they previously knew.

In short, this is all the product you've come to expect from DK, who are probably rivaled only by Haynes in terms of sheer ingenuity. If you're yet to discover their delights, start by getting this one for your budding young inventor. You won't regret it.

★★★★★



My STEM Day: Science

Your guide to everything around us

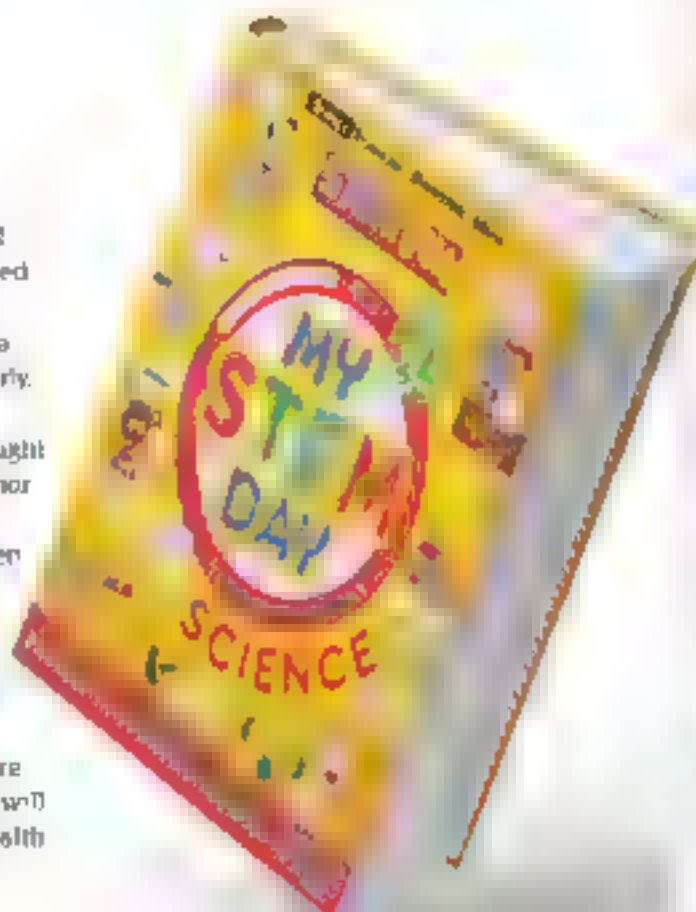
- Author: Anne Rooney
- Publisher: Carlton Kids
- Price: £7.99 (approx \$10)
- Release: Out now

STEM—science, technology, engineering and mathematics—is benefiting from an increased focus, and it's a handy thing to have some aptitude for. With that in mind, it's perhaps a good idea to get your kids familiar with it early, which is where this book comes in.

We always like science when it's being taught in a reliable and relevant way, and the author has clearly taken the same approach here, taking us through the processes that happen in accidents—like the school rule, teachers, and gardening. The diagrams that are included are helpful, but what caught our eye was the interactive guides, which really keep the focus on interactive learning.

We wish our textbooks at school were more like this. Even so, we're glad that kids today will have the opportunity to benefit from the wealth of accessible knowledge this book offers.

★★★★★



BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

L	W	O	H	W	S	N	K	H	J	V	H	P	E	O
X	A	N	L	G	S	I	S	A	D	E	Y	G	R	A
B	T	A	Z	J	E	C	Z	D	J	C	D	E	C	W
S	E	C	H	C	L	F	R	P	G	T	T	I	M	P
E	R	L	N	T	R	G	W	X	W	A	T	H	O	Q
Q	M	O	T	K	E	H	R	F	Z	C	I	L	N	Y
M	I	V	S	W	V	S	N	E	R	A	A	A	N	K
Y	L	F	Q	V	I	E	Y	A	B	R	D	O	D	L
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W	F	I	N	N	D	N	M	I	B	R	C	S	X	F
I	U	M	O	I	A	T	D	N	A	I	O	I	D	H
R	O	T	A	V	E	L	E	C	B	I	O	N	I	C
L	I	G	H	T	N	I	N	G	H	I	W	S	G	H
E	G	V	W	U	Q	B	B	V	T	H	T	Q	I	C
I	U	G	B	H	V	T	A	D	Y	Q	A	J	U	S

FIND THE FOLLOWING WORDS...

LIGHTNING
CARBON
BIONIC
ICEBERG
POLAROID
DRIVERLESS
ANTARCTICA
SYMBIOSIS
VOLCANO
GAIA
WATERMILL
ELEVATOR

Quickfire questions

Q1

Q2

Q3

Q4

Spot the difference

See if you can find all six changes we've made to the image on the right



Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		2	3	9			8	
	3			7				1
6		7				2		3
8		1		3		5	4	
2		5				3		6
	7	9		4		8		2
5		6				1		8
4				6			2	
	2			1	8	4		

DIFFICULT

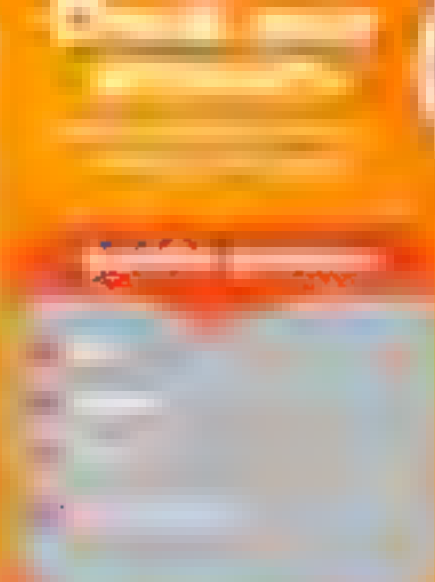
	9		5			2	4	
		7				6		
8		5			4		1	
	4		6					
5			1	7				9
				2		7		
	7		8			9		1
		8				7		
	5	6			1		8	

What is it?

It is a type of puzzle that is played on a 9x9 grid. The goal is to fill in the grid so that each row, column, and 3x3 box contains the numbers 1 to 9.



It is a type of puzzle that is played on a 9x9 grid. The goal is to fill in the grid so that each row, column, and 3x3 box contains the numbers 1 to 9.





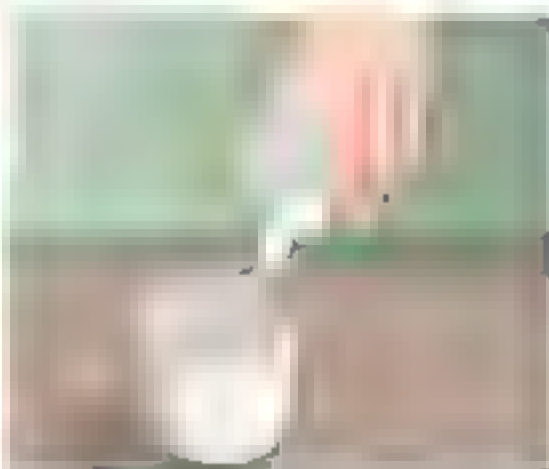
Make a fire snake

Create a snake using sugar, baking soda and an amazing chemical reaction



1 Create your insulator

To make your snake, first get a large bowl and then fill it with sand. Ask an adult to pour in a lighter fluid. Sand is fireproof and works very well as an insulator, so it should keep the heat protected while the snake starts to heat up.



2 Prepare your mixture

The lighter fluid will act as fuel and helps maintain the heat of the flame for longer. Next you need to mix ten grams of baking soda (sodium bicarbonate) with 40 grams of sugar. Pour this mixture onto the sand.



3 Light it up

To light the mixture, you'll need a long-necked lighter or a long-necked lighter. Ask an adult to help, and be very careful – the lighter fluid will ignite very quickly, so don't get too close to the flame.



4 Smoke black

After a little while, a large black blob will appear in the mixture and start to grow bigger. This is because as the baking soda and sugar get hot, they both release carbon dioxide gas, which begins to expand.



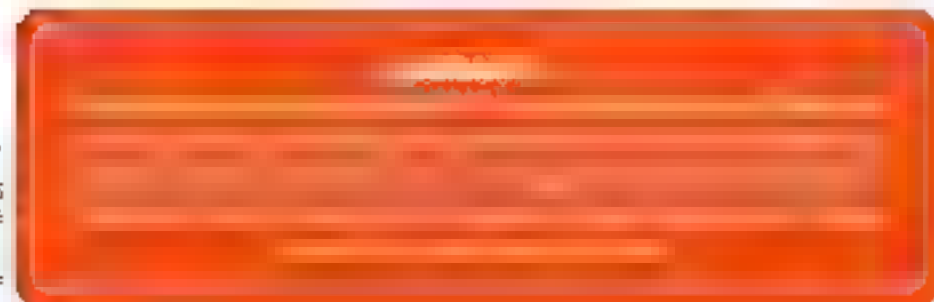
5 Carbon snake

The reaction also creates sodium carbonate, and as the carbon dioxide gas is created, the pressure pushes this upwards. The black colouring comes from the carbon in the mixture. It's getting big now!



6 The snake is lit

After a while – probably around 20 minutes – the flames will start to go out and the snake will stop getting bigger. All of the baking soda and sugar have been used up at this stage, so there's nothing left to burn.



Disclaimer: The authors of this magazine do not accept any liability for any adverse effects caused by the use of any of the projects or experiments. Always take care when handling potentially hazardous materials and follow the appropriate safety rules.

FREE

eBOOK BUNDLE



Book of the Elements

Since ancient times, scientists and philosophers have attempted to discover, classify and synthesise the Earth's elements. Now, thanks to the hard work of dedicated individuals, we have the periodic table: the ultimate guide to the elements, organised by atomic number and electron configuration. In the *How It Works Book of the Elements* we introduce you to the basics of elements and compounds, as well as taking a more in-depth look at the history of key discoveries. Every known element on the planet is covered in detail, from lanthanoids to actinoids, alkali metals to transition metals and halogens to noble gases. You'll find everything you need to know about the universe's building blocks right here.

Book of Combat Machines

The introduction of the first tanks during the Great War marked the start of an arms race that has continued to this day, and as we get our first glimpse at the next generation of military machines, it's incredible to think how far technology has come. In this new edition of *Book of Combat Machines*, we chart the history and development of these awesome military vehicles, from the fearsome German Tiger tanks of the Second World War, to the rise of the nuclear-powered submarine, to the hi-tech fighter jets that now rule the skies. We'll show you all the facts and figures you need to become a combat machine expert, as well as breaking down each vehicle for an inside look at the technology that makes these tanks, choppers and battleships tick.

Book of Amazing Technology

Today's world has been shaped by innovation in technology, so much so that modern life is incomparable to that of mere decades ago; how we communicate, travel and explore our world is almost unrecognisable. Smart gadgets and domestic inventions like mobile phones and drones have revamped our daily lives, but we often forget how the world has gradually evolved around us thanks to pioneering minds and engineering genius. So take a look around you and imagine what your life would be like without the amazing technology featured in this bookazine. It's time to celebrate the coolest concepts that have come to fruition, including robots, electric vehicles, interstellar travel, virtual-reality headsets and superdrones.

Claim yours now tinyurl.com/vxpzoyhg

FAST FACTS

Amazing trivia to blow your mind

**24
MEGATONS**

THE THERMAL ENERGY
RELEASED BY WASHINGTON'S
1980 MOUNT ST. HELENS
ERUPTION

610M

THE DISTANCE BETWEEN
TITANIC'S WRECKED BOW
AND STERN

520 MILLION-YEAR OLD
FOSSIL WORMS SHOW ONE
OF THE EARLIEST EXAMPLES
OF SYMBIOSIS

1820 THE YEAR FABIAN
VON BELLINGSHAUSEN
SIGHTS ANTARCTICA

5,472 KILOMETRES
IN 2015, A DRIVERLESS CAR
SUCCESSFULLY DROVE RIGHT
ACROSS THE USA

67% OVER TWO THIRDS
OF THE EARTH IS
COVERED IN CLOUD
AT ANY GIVEN TIME

WATERMILLS CAN BE
USED TO GENERATE
ELECTRICITY: AS
HYDROELECTRIC
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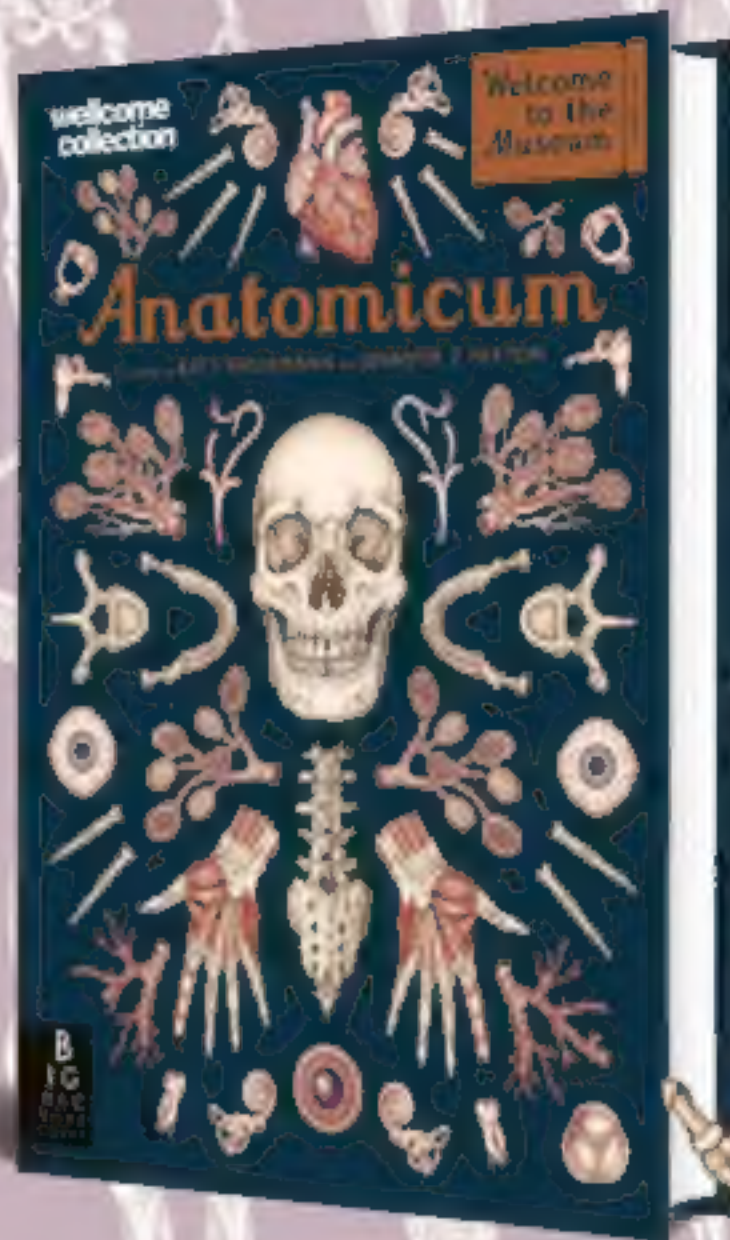
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